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The effect of response-independent reinforcement on the *re* parameter of Herrnstein's equation

by

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Dedication

To my mother and father

ABSTRACT

This research examines predictions from Herrnstein's single operant equation regarding the effect of response-independent reinforcement on human schedule-controlled behavior. It is postulated that a decrease in responding for response-dependent reinforcement in the presence of response-independent reinforcement will be reflected in an increase in the value of the r_e parameter of the equation. The response decrement will be greatest on leaner schedules where response-independent reinforcement constitutes the greater proportion of the total reinforcement received, as shown by a shift in the position of the hyperbolic curve which describes responding. This response decrement will also be evident when response-independent reinforcement takes the form of qualitatively different ongoing background stimulation.

These predictions, examined in a series of four experiments, are not upheld by the results. A tendency is found for schedule-controlled responding to increase and for r_e to decrease in the presence of response-independent reinforcement. The results are discussed in terms of their implications for the theoretical understanding of the r_e parameter, and for the use of Herrnstein's equation as a basis for generating applied behavior change techniques.

ABSTRACT

This research derives predictions from Herrnstein's simple operant equation regarding the effect of response-independent reinforcement on human schedule-controlled behavior. It is concluded that a decrease in responding for response-dependent reinforcement in the presence of response-independent reinforcement will be a function of an increase in the value of the r_o parameter of the equation. The response decrement will be greatest in [illegible] where response-independent reinforcement constitutes the greater proportion of the total reinforcement delivered, as compared to early in the acquisition of the experimental contingency or baseline responding. The response decrement will also be greater when response-independent reinforcement takes the form of qualitatively different, [illegible] reinforcement.

These predictions, examined in a series of four experiments, are not upheld by the results. A tendency is found for schedule-controlled responding to increase and for r_o to decrease in the presence of response-independent reinforcement. The results are discussed in terms of their implications for the theoretical interpretation of the r_o parameter, and for the use of Herrnstein's equation as a tool for describing applied behavior change [illegible].

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table		Page

LIST OF FIGURES

INTRODUCTION

The relationship between applied and basic behavior analysis has been the subject of recent debate (e.g. Deitz, 1978; Hayes, Rincover & Solnick, 1980). Several writers have expressed the view that recent developments in basic behavior analytic research are of potential but, as yet, generally unrecognized importance to the applied field. (Owens & Walter, 1980; Pierce & Epling, 1980). One such development, Herrnstein's (1970, 1974) quantification of the Law of Effect, has received considerable research and theoretical attention over the last decade from experimental behavior analysts, but has remained virtually unknown to applied workers. McDowell (1981a, 1982) has specified a number of ways in which Herrnstein's single-operant equation can aid the applied analyst in conceptualizing behavior and in designing behavior change strategies. His recommendations hinge on the theoretical interpretation of a particular parameter in the equation, $\underline{re}$. The aim of the present research is to investigate with human subjects the effects of certain operations on the $\underline{re}$ parameter: namely the delivery of response-independent reinforcement and alteration of background level of environmental stimulation. Herrnstein's equation

$$R = k(r/r+re) \qquad (1)$$

quantifies the relationship between response strength and reinforcement. $\underline{R}$ represents the strength of the target response, generally

measured in terms of rate of responding, and r is the rate or magnitude of reinforcement for that response. For example, R might be key-pecks per minute, while r would be food presentations per hour. The parameter k represents the asymptote of R in the absence of reinforcement for competing responses. It may be interpreted as a measure of the total behavioral output of the organism. It is expressed in the same units of measurements as R, i.e. key-pecks (responses) per minute. The second unknown, re, is said to represent all reinforcement impinging on the organism, other than r. It is measured in the same units as r, i.e. food presentations (reinforcers) per hour. The rectangular hyperbolic function obtained from the equation has been shown to account for much of the data variance in describing responding on variable interval schedules, both for animals in a variety of experimental situations (de Villiers & Herrnstein, 1976) and for humans on a button-pressing task (Bradshaw, Szabadi & Bevan, 1976a, 1976b, 1978, 1979).

Hernnstein's formulation emphasizes relative, rather than absolute, rate of reinforcement as a determinant of response strength. Response rate is governed by contingent reinforcement relative to all reinforcement supplied by the environment. In Equation 1, R, the actual response rate, is shown to be a fraction of the maximum behavioral output, k. This fraction is determined by the ratio of contingent to total reinforcement from all sources, (r/r + re). For instance, if r is large in relation to re, then R will be greater than if r is small in relation to re, even though r itself, the absolute rate of reinforcement for the target response,

does not change. Thus, a response could be increased or decreased leaving contingent reinforcement intact and instead altering reinforcement from some other source, since this would constitute a change in relative reinforcement.

Bradshaw and his colleagues (Bradshaw & Szabadi, 1978; Bradshaw, Szabadi & Bevan, 1976a, 1976b, 1978, 1979) have shown that Herrnstein's equation describes the operant responding of human subjects. These researchers have been concerned primarily with the effects of response-cost procedures on $\underline{k}$ and $\underline{re}$, and have given little consideration to the theoretical interpretation of these parameters (Bradshaw, Szabadi & Bevan, 1976a). A response-cost procedure involves the introduction of a punishment contingency on the target response, in addition to an ongoing reinforcement contingency. No research with human subjects has as yet investigated the effects on operant responding of procedures which involve the manipulation of other sources of reinforcement while leaving ongoing contingent reinforcement intact. Since Herrnstein (1970, 1974) defines $\underline{re}$ as representing these other sources of reinforcement, the result of such research would have implications for the interpretation of this parameter. The present series of experiments seeks to investigate the effects of other, non-contingent, reinforcement on rate of human operant responding and on the value of the $\underline{re}$ parameter.

Research of this nature is important not only in clarifying the theoretical interpretation of the $\underline{re}$ parameter, but also in

indicating what kinds of operations can be employed in applied settings in order to effect behavior change. Manipulation of contingent reinforcement in order to increase or decrease a response is characteristic of traditional behavior modification techniques. However, consideration of Equation 1 suggests other alternatives. Each of the behavior change strategies outlined by McDowell (1981a, 1982) relies on the manipulation of reinforcement other than that contingent on the target response. For example, the equation suggests that a) increasing rate of reinforcement for a specific concurrently available response, or b) increasing rate of "free" reinforcement[1] should result in a decrease in the target behavior even though contingent reinforcement does not change. The first strategy is familiar to applied behavior analysts as differential reinforcement of other behavior (DRO), and is often referred to as reinforcing a response "incompatible" with some problem behavior (Martin & Pear, 1978). However, as McDowell points out, in terms of Herrnstein's equation the incompatibility of the alternative response is irrelevant. What is important is the change in the rate of reinforcement for the target response relative to all reinforcement available.

The second strategy, increasing the rate of response-independent reinforcement, is of particular interest in view of the dearth of research on this topic. McDowell (1981a, 1982) suggests that the humanistic therapists' technique of giving "unconditional positive regard" (Rodgers, 1951) might be viewed as providing an increase in r_e. In applied behavioral studies this kind of strategy has

been used, not with therapeutic intent, but as a control technique in reversal (ABAB) designs. In this procedure, reinforcement is made contingent on a target response after measuring its operant level. Then, to demonstrate that the increase in responding is due to the reinforcement contingency, while controlling for the effects of total removal of reinforcers from the situation, reinforcement continues to be delivered, but independently of responding. This generally results in a decrease in the behavior of interest, as would be predicted from the equation, since contingent reinforcement (r) is reduced, while other reinforcement (re) is increased. The technique of providing higher rates of non-contingent reinforcement in a therapeutic attempt to decrease an undesirable behavior has practical value in an applied setting, as no specific alternative behavior need be monitored and reinforced. The lack of basic experimental research on the effects of free reinforcement on human responding and the potential cost-effectiveness of such a technique in behavior modification indicate the need for further study of this topic. The purpose of the second and third experiments in the present series is therefore to investigate the effects of response-independent reinforcement on human operant responding maintained by contingent reinforcement, using the same basic task as in the first experiment.

Herrnstein (1970, p. 258) refers to the denominator of the equation as "a 'context' of reinforcement" and McDowell amplifies this notion by suggesting that environments may be assessed in terms of their "richness" by finding the values of re associated

with them. Such an assessment would be useful in therapeutic program planning, as the equation suggests that the same rate of contingent reinforcement will have different effects on the rate of the target behavior depending on whether it is delivered against a rich or a lean reinforcing background. The effects of institutional environments on vulnerable populations such as the mentally retarded have long been recognized, but few empirical studies exist (Horner, 1980). Thus, the purpose of the final study is to examine the proposition that <u>re</u> provides a measure which is sensitive to the general reinforcing qualities of the environment. The same task is used as in the previous experiments but the context in which it is performed is altered.

In conclusion, there is evidence that the hyperbolic form of Herrnstein's equation describes human responding. However, there has as yet been no attempt to investigate directly predictions based on the interpretation of the <u>re</u> parameter. If <u>re</u> is defined as reinforcement from all sources other than <u>r</u>, then theoretically the addition of response-independent reinforcement must inevitably result in a decrease in <u>R</u> and an increase in <u>re</u>. If <u>R</u> fails to increase by this procedure, then some refinement of the parameter's definition is indicated. Furthermore, investigation of the operations which influence the <u>re</u> parameter is of importance in substantiating the behavior change strategies suggested by McDowell on the basis of Herrnstein's equation.

The present series of experiments tests four major hypotheses:

1. The form of the relationship between human response rate and rate of reinforcement will be hyperbolic, in accord with Herrnstein's equation (Equation 1).

2. The delivery of response-independent reinforcement concurrently with response-dependent reinforcement will result in a decrease in response rate and an increase in the value of the *re* parameter.

3. The decrement in response rate under the above conditions will be greater on leaner schedules, where response-independent reinforcement constitutes the greater proportion of the total.

4. Increasing the background level of reinforcement will result in a decrease in response rate and an increase in the value of *re*.

LITERATURE REVIEW

Herrnstein's Equation: Theoretical Considerations

In continuous choice procedures the organism is free to respond to any one of several alternative schedules of reinforcement which are simultaneously available. There is considerable evidence that in such a situation subjects "match" the distribution of their responses to the distribution of the reinforcers (de Villiers & Herrnstein, 1976; de Villiers, 1977). This matching relation may be formally stated

$$R1/(R1 + R2 \ldots + Rn) = r1/(r1 + r2 \ldots + rn) \qquad (2)$$

where $\underline{R}$ symbolizes rate of responding on an alternative and $\underline{r}$ the associated rate of reinforcement.

Herrnstein (1970) argues that relative rate of reinforcement must determine not only relative response rate, as in the matching equation, but also absolute rate of responding on each concurrently available alternative. In this formulation, choice has no distinctive psychological features, but is regarded as "merely behavior in the context of other behavior." (de Villiers & Herrnstein, 1976, p. 1132). The organism is seen as confronted with a set of response alternatives among which behavior is distributed. This is so regardless of whether only a single response is monitored by the experimenter and whether alternative reinforcers are identifiable or not. On

the basis of this assumption, Herrnstein (1970, 1971, 1974) proposes that absolute rate of responding is proportional to the overall relative rate of reinforcement.

Assuming a situation in which only two response alternatives are available, if _k_ represents asymptotic response rate when there are no reinforcers other than _r_, then

$$k = R1 + R2 \tag{3}$$

Substituting in the matching equation,

$$\text{a)}\quad R1/k = r1/r1 + r2 \qquad R1 = kr1/r1 + r2 \tag{4}$$

$$\text{b)}\quad R2/k = r2/r1 + r2 \qquad R2 = kr2/r1 + r2 \qquad \text{"}$$

$$\text{c)}\quad R1/R1 + R2 = \frac{kr1/r1 + r2}{kr1/r1 + r2 \; + \; kr2/r1 + r2} = r1/r1 + r2 \qquad \text{"}$$

Thus, responding on each alternative is described by an equation having the same form as the single operant equation. Note that for each alternative the operation of unspecified reinforcers is taken into account by the inclusion of the parameter _re_ in the denominator:

$$R = kr1/r1 + r2 + re \tag{5}$$

which, in a single response procedure becomes

$$R = kr1/r1 + re \qquad (6)$$

Herrnstein (1974) considers that the single operant equation affords a more fundamental means of describing behavior than the matching law, since it entails the measurement of absolute rather than relative response rate.

The k parameter. To preserve the integrity of the matching relation in the single operant setting, it is necessary that *k* remain constant across responses with the same topography regardless of differences in reinforcement associated with each response. This must be the case, otherwise the *k* values in Equation 4 would not cancel out to yield matching. Thus, a major theoretical requirement is that *k* should not vary with changes in reinforcement whether from known or unknown sources (Hernnstein, 1970, 1974).

Herrnstein interprets *k* as "the modulus for measuring behavior" (1974, p. 163). Three properties of the parameter contribute to this definition. First, *k* measures asymptotic response rate in the absence of reinforcers other than *r*, that is, when *re* = 0. Second, as shown in Equations 4a and 4b, *k* is that rate of response which yields matching when divided into *R*. Third, it represents "the total amount of behavior generated by all the reinforcements operating on the subject at a given time" (Herrnstein, 1974, p. 161), or, as it is termed here, total behavioral output. Herrnstein notes that in order to prevent violation of the matching relation, *k* must include some quantity of behavior which corresponds to

reinforcers other than _r1_ and _r2_. This behavior is here termed _Re_. Consider Equations 4a and 4b. If another source of reinforcement, _re_, is added to the denominator, _R1_ and _R2_ must decline. If _k_ is then still the sum of _R1_ and _R2_ the matching relation would not hold. This is so because

$$(R1 + R2)/k = (r1 + r2)/(r1 + r2) = 1 \tag{7}$$

but

$$(R1 + R2)/k = (r1 + r2)/(r1 + r2 + re) \neq 1 \tag{8}$$

Therefore, to preserve the integrity of the matching relation, _k_ is assumed to be composed of _R1_, _R2_ and _Re_, such that even if _R1_ and _R2_ decline, _Re_ compensates for the decrease so that _k_ remains constant. This is important in considering the _re_ parameter and, in particular, the means by which it may be manipulated.

The re parameter. In his 1970 paper, Herrnstein used the expression "ro" to mean "the unknown, aggregate reinforcement for other alternatives" (p. 255), implying that there are behaviors on which these unknown reinforcers are contingent. However, in 1974, the definition of _ro_ was restricted to "reinforcements that come spontaneously" (p. 160).

Writing the single operant equation in its general form

$$R1 = kr1/\sum_{i=0}^{n} ri$$

he comments

> Note...that the summation extends from (*ro*) upwards. This notation is used to suggest that there may be reinforcements that are not conditional upon responses, and which therefore come independently of action (and for which we could not therefore find an instrumental response even if we looked). The denominator includes *all* reinforcements, even the spontaneous ones. The correct interpretation of n, therefore, is that it enumerates the *instrumental* sources of reinforcement -- those dependent upon responses to produce them. The *total* number of sources, counting spontaneous reinforcements as a single source is n + 1. (1974, p. 160).

The expression *re* was adopted to cover both previous senses of *ro* and thus to encompass all extraneous sources of reinforcement, whether conditional on responses other than the target or occuring "spontaneously", i.e. independently of responding (de Villiers, 1977). The *re* parameter is therefore currently interpreted as the total reinforcement available to the organism besides *r*1 (de Villiers, 1977). The denominator of the equation has also been referred to as "background level of reinforcement" (de Villiers & Herrnstein, 1976; Herrnstein, 1979).

It is evident, then, that the postulation of _Re_, discussed in the previous section, although theoretically necessary to preserve the integrity of the matching relation, does not imply that the unknown reinforcers contributing to _re_ must be contingent on any particular response. Herrnstein is quite specific on this point when he states that

> It may strike some as frivolous to assume that we must talk about responses consumed by the obtaining of spontaneous reinforcements, which by definition are independent of any correlation with response. Nevertheless, the logic of matching once again leaves us no alternative (1974, p. 161).

In making clear that the value of the equation's denominator can never be entirely determined by experimental manipulations, Herrnstein even postulates "internal" sources of _re_. For example, "A creature's own body and its physiological processes introduce a background level of hedonic affect that puts the denominator beyond total control" (1974, p. 160). Although the value of _re_ may not be entirely subject to control, it can nevertheless be influenced by experimental manipulation. Herrnstein (1974) cites a study by Rachlin & Baum (1972) in which response-independent reinforcement was delivered concurrently with response-dependent reinforcement as a means of affecting _re_. This study will be examined in the subsequent review of the empirical literature.

The Quantitative Law of Effect: Alternative Formulations

Herrnstein's equation is one of several quantitative approaches to the description of behavior. These other accounts have received little research attention, but are reviewed briefly here in view of their predictions regarding the status of $\underline{k}$.

Catania (1973) proposed an equation which is mathematically similar in form to Herrnstein's but based on the theoretical assumption of "self-inhibitory" effects of reinforcers. This view postulates that reinforcers have both excitatory and inhibitory effects on the responses which produce them, as well as inhibitory effects on all other responses. The function which relates responding and reinforcement is due to the joint operation of these processes. Both formulations make similar predictions, and empirically there seems little evidence to justify a choice between them (Catania, 1973).

Staddon (1977) discusses the derivation of a quantitative formulation of the Law of Effect from two different bases. The first approach, similar to Herrnstein's, regards this equation as "the steady state[2] solution for a process in which responding to two alternatives is driven in one direction or the other by reinforcement for each alternative" (Staddon, 1977, p. 169). This approach, he points out, can also lead to a power function model (see Baum & Rachlin, 1969; Baum, 1974). Staddon's second approach takes into joint account constraints of time allocation, which serve to limit maximum response rate, and the fact that on interval schedules the probability of reinforcement increases over time

since the last response. (Herrnstein's equation is most aptly applied to interval schedules. de Villiers & Hernnstein, 1976) The formulation derived in this manner predicts a correlation between _k_ and _re_, which is contrary to Herrnstein's assertion that _k_ is independent of changes in reinforcement.

McDowell (McDowell & Kessel, 1979; McDowell, 1980) has developed a multivariate rate equation from a linear systems analysis of variable interval schedule performance. This account views rate of response as a function of both rate and "power", or value, of reinforcement. The power parameter takes into account characteristics of reinforcement such as amount, immediacy, and duration. This equation fits empirical data as well as Herrnstein's (McDowell & Kessel, 1979), but the rate equation appears to have some advantage, in that it predicts both undermatching and bias on concurrent schedules (Baum, 1974), which Herrnstein's matching equation in its simple form cannot do. Importantly, it also calls into question Herrnstein's invariance requirement for _k_. The rate equation predicts that k will vary with changes in reinforcement parameters. This, as McDowell points out, destroys the relationship between the single-operant and matching equations and casts doubt on Herrnstein's conception of choice as the basis for single operant behavior.

Herrnstein's equation has the advantages of simplicity and historical precedent, and has generated considerably more research than the other formulations. However, the alternative predictions of Staddon and McDowell indicate the need for further research on

the operation of Herrnstein's parameters.

Empirical Investigation of Herrnstein's Equation

De Villiers (1977) and de Villiers and Herrnstein (1966) have calculated, on a post hoc basis, the fit of the hyperbolic function generated by the single operant equation to data from a wide variety of animal studies. Rats, pigeons and monkeys were used as subjects, with behaviors varying from lever pressing to running in an alley, and reinforcers as diverse as food, escape from shock and brain stimulation. De Villiers summarizes

> Out of 53 tests of (the equation) on group data, the least squares fit of the equation accounts for over 90% of the variance in the dependent variable in 42 cases, and for over 80% in another 6 cases. Out of 45 tests on individual data, the equation accounts for over 90% of the variance in 32 cases, and for over 80% in another 7 cases. (de Villiers, 1977, p. 262).

In all but one of the cases in which the equation did not account for most of the data variance, the variance was negligible. Some of these studies varied drive level, quantity, or quality of reinforcement across conditions, thus allowing for a test of the constancy of *k*. Considering only those cases in which over 90% of the variance was accounted for, in 5 studies (Guttman, 1954;

Kraeling, 1961; Logan, 1960; Seward, Shea, Uyeda & Raskin, 1960; Woods & Holland, 1966) the obtained k values were very similar, while in 3 cases discrepancies were found over different conditions (Campbell & Kraeling, 1973; Keesey, 1964; Schrier, 1965). A later experiment by Bradshaw, Szabadi & Bevan (1978b) found that for rats pressing a lever on a variable interval schedule for sucrose reinforcement, k was a monotonically increasing function of sucrose concentration. Thus, while the fit of the equation to animal data is very good, the constancy of k is called into question.

As for re, studies are lacking in which the actual values of this parameter have been calculated for the same behavior in conditions where reinforcement other than for the target behavior has been varied. However, there are many animal studies which investigate the effects of other sources of reinforcement on operant behavior, with results which have relevance for the equation's predictions. For example, continuous choice procedures using concurrent schedules have implications for the interpretation of re. Given two concurrently available response alternatives, A and B, the reinforcement available for A contributes to re for B and vice-versa. Responding on A is therefore expected to vary inversely with the rate of reinforcement obtained on B. This predicted contrast effect was investigated by Catania (1963). He used a signalled reinforcement procedure to vary the rate of reinforcement for one alternative of a concurrent schedule, while keeping responding at a low level. On key A, reinforcement was programmed according to a standard variable interval (VI) schedule.

On key B, a signal light indicated the availability of each reinforcer as it was set up. Consequently, pecking occurred almost exclusively on key A, and on key B only when a reinforcer could be collected. He then varied the value of the VI on the signalled key, and found that responding on key A varied inversely with key B reinforcement, but was independent of responding on key B. This finding has been confirmed by Rachlin and Baum (1969). Together these studies indicate that rate of reinforcement from a concurrent alternative determines rate of target behavior, and that the rate of alternative responses is not a critical factor in the control of the target behavior. This is in line with the prediction from Equation 1 that an increase in alternative reinforcement (re) leads to a decrease in responding. Bradshaw (1977) confirmed this with rats, but found that the actual degree of response suppression was greater than that predicted by the equation.

The Effects of Response-independent Reinforcement on Operant Responding

Catania's (1963) and Rachlin and Baum's (1969) experiments demonstrate the effects on responding of reinforcement which is contingent on a specific alternative response. However, as has been shown, Herrnstein's definition of re also includes "spontaneous", or response-independent reinforcement, which is the particular focus of the present research. The equation predicts that increasing re, in the form of response-independent reinforcement, should lead to a decline in the rate of the target response. There are no previous studies which have directly investigated the provision of response-independent reinforcement as a factor

influencing re. However, there are a number of experiments which investigate the effects of response-independent reinforcement on operant responding. Although these experiments were not conducted within the context of Herrnstein's equation, they do have a bearing on the prediction that the delivery of response-independent reinforcement serves to decrease operant responding.

Studies which allow a comparison of response rate in a condition in which only response-dependent reinforcement is delivered with rate in a condition where response-independent reinforcement is concurrently available are of particular relevance. That is, while the subject responds on a schedule which delivers reinforcement contingent on responding, another schedule simultaneously delivers reinforcement which is independent of responding. Such an arrangement conforms to Ferster and Skinner's (1957) definition of concurrent schedules as "two or more schedules independently arranged but operating at the same time, reinforcements being set up by both" (p. 724). However, in this case there is no changeover delay (COD), as in the conventional continuous choice procedure, and "concurrent" refers to the scheduling of alternative sources of reinforcement rather than the availability of alternative responses. Indeed, the term "alternative reinforcement" has been used to describe this arrangment (Rachlin & Baum, 1972; Lattal & Boyer, 1980). The inclusion of a COD, such that for example the subject chooses between a variable interval (VI) and a variable time (VT) schedule, would render the time-scheduled reinforcement no longer response-independent, as it would become

in effect reinforcement for not responding (Lattal & Bryan, 1976). To denote the use of the alternative reinforcement paradigm rather than the COD concurrent paradigm, I will refer to the former as a VI + VT (or FI + VT, etc.) schedule.

A small number of studies have used some form of the alternative reinforcement paradigm with either fixed or variable schedules of reinforcement. Edwards, Peek and Wolfe (1970) trained rats to respond on a fixed ratio (FR) schedule for sucrose. This was then followed by fixed time (FT) presentations of sucrose, either alone or simultaneously with the response-dependent sucrose, in which case inter-reinforcement intervals (IRIs) for the independent presentations were systematically decreased. FR response rates for both subjects declined during presentation of response-independent reinforcement and reached 0 when the IRIs were reduced by 1/2 and 1/8 respectively. In their second experiment, in which response-independent IRIs were held constant and FR sizes were systematically manipulated, response rates declined as a function of decreases in ratio size. This experiment therefore indicates that responding for reinforcement decreases in the presence of response-independent reinforcement, and suggests that the magnitude of the decrease relates to the proportion of response-independent to total reinforcement.

Lattal and Bryan (1976), after training pigeons on an FI schedule, introduced a superimposed VT schedule. As the frequency of VT reinforcement was systematically increased, FI responding decreased to below baseline rate. A second experiment in which a

MULT FI FI schedule was changed to MULT (FI + VT) (CONJ FI VI) showed that for three of four subjects, response rate was lower during the FI + VT component than during the corresponding single FI component. A further experiment alternated periods of responding on single FI schedules with periods of FI + FT reinforcement. When FT 1 min. was added to FI 3 min. responding decreased below baseline, but when FT 0.33 min. was added to FI 1 min. only one of the three subjects showed a decrease in rate. On the whole, however, the work of these researchers supports the prediction of a decrease in responding with the introduction of response-independent reinforcement.

Deluty (1976) trained rats to respond on a random interval (RI) schedule. (This schedule is described in detail in Footnote 3 but is a form of VI schedule). Then, additional response-independent reinforcement was delivered according to an FT schedule in one experiment and a random time (RT) schedule in another. With the RI schedule held constant, rates of response-independent reinforcement were systematically manipulated. In both experiments responding decreased as a function of increases in the rate of response-independent reinforcement. In addition to providing further support for the inverse relationship between overall rate of responding and rate of response-independent reinforcement, Deluty also investigated effects on local response rate. Results indicated that as well as the overall inhibitory effect, response-independent reinforcement delivery had a local excitatory effect, in that responding increased to above its mean level immediately following delivery of such a reinforcer, with both fixed and random time

schedules, and decreased thereafter.

A study by Lattal (1974) provides further systematic investigation of the role of the relative proportions of response-dependent and response-independent reinforcement in controlling rate of behavior. Pigeons first attained stable responding on a VI schedule, which was then changed to an analagous VT. Thereafter, subjects were exposed to sequences of different combinations of response-dependent and response-independent reinforcement, in either ascending or descending order. The effects of 100%, 66% (for one of the five subjects only), 33%, 10% and 0% response-dependent reinforcement were studied. Response rates fell below VI baseline in all conditions scheduling response-independent reinforcement and were systematically related to the percentage of response-dependent reinforcement. That is, as other studies reviewed have also indicated, the greater the proportion of response-independent reinforcement, the lower the rate of responding.

Finally, Rachlin and Baum (1972) report an experiment in which, in one condition, pigeons responding on a VI schedule were exposed to additional VT reinforcement. During baseline and the subsequent return to baseline phase, equal rates and amounts of reinforcement were provided on both schedules. In the intervening phase, either rate or amount of response-independent reinforcement was varied and in both cases a decrease in response rate was found such that "the more response-independent reinforcement, the lower the rate of pecking" (Rachlin & Baum, 1972, p. 238). Indeed, this finding also held for other experimental conditions, in which the

additional reinforcements were either signalled or available after a 2 sec. pause, and whether amount or rate was varied.

This is the only study to relate this result directly to Herrnstein's equation and to provide evidence regarding its fit to the data. A variant of Herrnstein's equation was used, and was applied to data from all experimental conditions, not only those involving response-independent reinforcement. The equation was found to fit the data with $\underline{k}$ of 210 and an $\underline{re}$ of 240. However, response-independent reinforcement was represented in the equation as a separate source, $\underline{r2}$, with $\underline{re}$ representing "unknown" reinforcers. Thus, not only does Rachlin and Baum's study support the prediction of an inverse relationship between rate of responding and response-independent reinforcement, but it also suggests that Herrnstein's hyperbolic function aptly describes responding under such conditions.

In most of the experiments reviewed in this section the two sources of reinforcement were not distinguishable either by the location of their delivery or by the presence of distinctive discriminative stimuli. The exception is Deluty's (1976) study, in which free reinforcers were accompanied by a brief burst of white noise. However, the omission of the noise did not alter the results. It could therefore be suggested that the decrease in responding is simply due to the strengthening of behaviors other than the target response by the occasional delivery of response-independent reinforcement during periods of non-responding. However, Rachlin and Baum's (1972) study included a condition in which "free" reinforcers were delivered only after 2 sec. of non-responding. This delayed response-independent reinforcement condition is

similar to a differential reinforcement of other behavior (DRO) schedule, and could be expected to result in an even greater response decrement, since the time-scheduled reinforcement always followed a period of non-responding. However, the decrease in responding in this condition was no greater than when no such pause was required. similarly, Zeiler (1976) found no difference in response reduction on an FI schedule with alternative reinforcement delivered either on an FT or on a DRO schedule. Rachlin and Baum comment:

> It seems more likely that molar correlations between responding and reinforcement, or the lack thereof, controlled the discrimination of the two sources of reinforcement. The pigeons must have been sensitive to these correlations irrespective of whether, in particular instances, a given reinforcer followed a given response (1972, p. 238).

Deluty's (1976) study, in which local increases in responding followed response-independent reinforcement delivery but were nevertheless accompanied by an overall response decrement would tend to support this view.

Two studies have employed a VI + VT schedule as a component of a multiple schedule. Boakes, Halliday and Poli (1975) used a procedure in which pigeons were trained on MULT VI VI, using identical

VI schedules in the two components. Then, a VT schedule was added in the second component. In terms of the equation, provision of response-independent (VT) reinforcement constitutes an increase in $\underline{re}$, and should therefore have the effect of decreasing responding in the VI + VT component as compared with responding in the original, VI only, second component. A decrease in the unchanged VI component might also be anticipated, due to the overall increase in reinforcement in the second component. However, Boakes and his colleagues found that while response rate decreased in the unchanged component, in the VI + VT component, responding increased. However, the experiment was repeated using rats, and response rate did indeed decrease in both components, with rate in the VI + VT component lower than rate in the VI only component. A third experiment confirmed the latter findings. Thus, there is some support for the prediction of a decrease in operant responding in the presence of response-independent reinforcement, but with an indication of possible species differences.

In this respect, it is interesting to consider the findings of Rachlin (1973) and Green and Rachlin (1975) who also used a MULT VI VI + VT procedure, with pigeons. Since they did not pre-train on MULT VI VI, the relevant comparison is between response rate during the first, VI only, component, and the second, VI + VT component. Herrnstein's formulation would predict a lower response rate during the second component, in the presence of response-independent reinforcement. However, these researchers found that whether response rate in the second component was higher or lower

than rate in the first component depended on the duration of the components. This finding is in line with their theoretical account. They suggest that two principles govern responding in this situation. Their "economic principle", a restatement of the Law of Effect, affirms that "a stimulus signalling a period of low reinforcement value will be exchanged ... for a stimulus signalling a period of high reinforcement value" (Rachlin, 1973, p. 234). The "biological principle" has to do with the interaction of the response with the stimulus associated with reinforcement, as in autoshaping (Brown & Jenkins, 1968). The former is a steady-state effect, while the latter is assumed to operate most strongly immediately following transition to the component with higher reinforcement value, and dissipates over time. On this basis they predicted that, given a MULT VI VI + VT, with short component durations responding would be faster in the second component due to the operation of the biological principle. Also, as duration increased, the economic effect would predominate and rate in the VI + VT component should decrease and eventually be lower than rate in the VI component. The results of both experiments confirmed these predictions.

Herrnstein's equation makes the same predictions as Rachlin's economic principle, but does not take into account any biological connection between response and reinforcer. Such a connection would not be relevant in the case of humans pressing a button for points as reinforcers, and is perhaps only of relevance in experiments in which pigeons key-peck for food. In such experiments,

the presentation of response-independent food for short periods along with response-dependent food could elicit a higher rate of pecking, in the manner of autoshaping. This could account for Boakes, Halliday and Poli's (1975) finding of an increase in rate of responding when the VT schedule was introduced in the second component of their MULT VI VI schedule only when pigeons were used as subjects. Component duration in their experiment was 2 min., while Green and Rachlin (1975) noted the predominance of the economic effect at a duration of 8 min. When rats were used in the Boakes et al study, the decrease predicted by Herrnstein's equation in the presence of response-independent reinforcement was indeed observed. In Rachlin's terms, only the economic effect was evident, regardless of short component durations, and this was perhaps due to the lack of a biological connection between lever pressing and food acquisition.

Studies of positive conditioned suppression are also of interest. In human laboratory research the use of conditioned reinforcers such as tokens, points, money, etc. is the general rule. Although there is no equivalent animal research in which conditioned reinforcement constitutes both sources in the alternative reinforcement paradigm, there are a few studies in which a conditioned reinforcer is delivered independently of responding for a primary reinforcer. This is the positive conditioned suppression paradigm. In the traditional conditioned suppression paradigm (Estes & Skinner, 1941), presentation of a conditioned stimulus (CS) terminating in an aversive event is superimposed on a baseline of operant responding.

Responding is generally found to decrease during CS presentation. Such suppression of responding has, however, also been found to occur when the CS is a conditioned reinforcer. That is, when it is associated with an unconditioned stimulus (UCS) which is a positive reinforcer, hence the term positive conditioned suppression. For example, rats and squirrel monkeys responding for food on VI schedules have been found to decrease responding during brief response-independent presentations of a CS which preceeded food, water or intracranial stimulation (Azrin & Hake, 1969; Meltzer & Brahlek, 1970; Hake & Powell, 1970; Miczek & Grossman, 1971). However, such results have not been consistently obtained, and response increases (Herrnstein & Morse, 1957) and no effects have also been observed with this paradigm. Several factors contributing to these divergent findings have been isolated, for example CS duration (Henton & Brady, 1970; Meltzer & Brahlek, 1970; Miczek & Grossman, 1971; Smith, 1974), baseline reponse rate (Smith, 1974), and the additive effects of auoshaped responding to the CS (LoLordo, 1971; LoLordo, McMillan & Riley, 1974). Thus, although it has been found that response-independent conditioned positive reinforcement suppresses responding, this is by no means a general result, and appears to depend on a number of factors.

To summarize, the animal experiments reviewed here lend general support to the prediction of a decrease in responding for response-dependent reinforcement when response-independent reinforcement is also made available. There is some suggestion that under certain circumstances response-independent conditioned reinforce-

ment may have similar effects. However, some findings indicate possible species differences in the effects of response-independent reinforcement on reinforced operant responding. This emphasizes the need for research on this topic with humans as subjects.

Herrnstein's Equation and Human Operant Responding

There has been no previous attempt to investigate the effects of response-independent reinforcement on schedule controlled human responding in the context of Herrnstein's equation. However, a series of studies by Bradshaw and his colleagues has investigated the applicability of Equation 1 to human responding on VI schedules (Bradshaw & Szabadi, 1978; Bradshaw, Szabadi & Bevan, 1976a, 1976b, 1977, 1978, 1979). As the present research employs Bradshaw et al's basic research procedure this is described here in some detail.

The first phase of Bradshaw, Szabadi & Bevan (1976b) exemplifies the basic procedure. Four subjects were exposed to 5 different VI schedules, ranging from lean (5 rft/hr) to rich (211 rft/hr). Each schedule was presented for 10 min. in each session, with 5 min. rest periods separating schedule presentations. The order of presentation was randomized. Each schedule was associated with one of 5 amber lights mounted on the response panel. This light remained on for the 10 min. during which its schedule was in effect. Subjects responded by pressing a button and reinforcement consisted of the delivery of a point to a counter. The accummulated points were later exchanged for money. The delivery of each point was accompanied by the brief illumination of a green light. Sessions took place on 15 consecutive weekdays.

Stability of responding was judged from cumulative records, and the mean response rate for each subject over the final 5 sessions was plotted against reinforcement rate. It is customary to plot obtained rate of reinforcement, but in this case obtained reinforcement was within 5% of scheduled reinforcement and so scheduled reinforcement rate was plotted instead. Wilkinson's (1961) non-linear regression method was used to determine the fit of the hyperbolic function. The percentage of variance in responding explained by the equation and the estimated values of $\underline{k}$ and $\underline{re}$ in terms of responses per minute and reinforcers per hour respectively are shown in Table 1, along with results from other of Bradshaw's studies. The finding that the hyperbolic function is descriptive of human button pressing on VI schedules has been replicated by McDowell (Note 1) and, for some subjects, by Wearden, Lochery and Oliphant (Note 2). Their results are also included in the table.

-- Insert Table 1 about here --

Bradshaw's data indicate a very good fit of the function. In most cases, over 90% of the variance in responding is explained. For Wearden's subjects, however, the function describes the data adequately in only 4 out of 8 cases. There is also far greater variability in the $\underline{re}$ values obtained by Wearden than by Bradshaw. Since Wearden and his colleagues also used Bradshaw's basic procedure, these discrepancies point to the need for further investigation with humans and, in particular, consideration of the factors affecting $\underline{re}$.

Two subjects in the Bradshaw et al (1976b) study, SM and AM, participated in a second phase. The same 5 schedules (now referred to as the A component schedules) remained in effect but were presented concurrently with a VI 51 sec. (B component) schedule on which subjects could respond by pressing a changeover button. The situation now represents a CONC VI VI schedule with reinforcement varied in one component (A) and constant in the other (B). Relative rates of responding conformed to the matching relationship and for both subjects responding on the B schedule decreased with increases in the rate of reinforcement provided in component A. While there was no difference in _k_ values for the two phases, the _re_ values were considerably greater in Phase 2, as would be predicted, since the introduction of the VI 51 sec. schedule represents an increase in _re_ for the A component. These results are also presented in Table 1. In comparison with the Phase 1 function, the Phase 2 function is shifted downwards especially at the lower end, giving it a flatter appearance, although it tends towards the same asymptote. This indicates, as the equation predicts, that the effects of other reinforcers (_re_) are greater where they constitute the greater proportion of total reinforcement. This inverse relationship between response rate on one component of a concurrent schedule and reinforcement rate in the other was further investigated by Bradshaw, Szabadi, Bevan and Ruddle (1979), using a signalled reinforcement procedure such as that employed with animals by Catania (1963) and Rachlin and Baum (1969), as outlined earlier. However, Bradshaw et al (1979) report findings at variance with those of the other investigators. Signalling

availability of reinforcement did indeed decrease responding in the signalled component, but a concommitant increase in responding in the other component was found. This would indicate a reciprocal relationship between rates of responding on the two schedule components, rather than between rate of responding on one and rate of reinforcement on the other, as shown in the animal studies.

The results of the series of studies by Bradshaw and his colleagues show that Herrnstein's equation can describe the operant responding of human subjects, and provide support for the prediction that introducing other sources of reinforcement increases r_e and decreases responding. However, the results of the signalled reinforcement procedure indicate the need for further research with human subjects on the relationship between rate of response and rate of alternative reinforcement.

GENERAL METHODOLOGY AND DESIGN

An adequate evaluation of the predictions of Equation 1) concerning the effects of response-independent reinforcement requires that subjects' performance conform to the hyperbolic function. Since Bradshaw and his colleagues have replicated the fit of the function to human responding in several experiments, their core procedure provides a basis from which to investigate response-independent reinforcement effects. This procedure, outlined in the previous section, was followed here with two modifications.

First, the present research employs random interval (RI) schedules equivalent in value to the VI schedules used by Bradshaw, Szabadi and Bevan (1977, 1978, 1979). Random interval schedules can be easily constructed using Coulbourn programming modules and do not require the making and changing of tapes. They were chosen primarily for this convenience. Their use is also justified by other considerations. Bradshaw describes his VI schedules as "constant probability" schedules (Catania & Reynolds, 1968), and the RI schedule (Farmer, 1963; Millenson, 1963) is the primary example of a constant probability schedule.[3] Further, Rodewald (1978) has shown that matching data obtained from CONC RI RI schedules are consistent with those obtained using CONC VI VI schedules when the former are constructed to approximate VI rather than FI. Deluty's (1976) study also provides precedent for testing the effects of response-independent reinforcement on RI responding.

Second, Bradshaw's subjects participated for one session on consecutive weekdays, consisting of 10 min. presentations of each schedule separated by 5 min. rest breaks. While Experiment I of the present series followed this procedure, in subsequent experiments 3 sessions per subject per day were conducted with 10 to 15 min. rest periods between sessions, and inter-schedule breaks were reduced to 2 min. This procedure was adopted for practical reasons (limited availability of laboratory time and the fact that a transit strike made it more convenient for subjects to attend for longer blocks of time on the same day). The experimental manipulation, in this case the introduction of response-independent reinforcement, was in force on alternate sessions as in the Bradshaw studies (Bradshaw, Szabadi & Bevan, 1977, 1978, 1979). The experimental design might therefore be characterized as an alternating AB design, with rate of response as the dependent variable and presence/absence of response-independent reinforcement as the independent variable.

It should be noted that while Bradshaw et al use Wilkinson's (1961) prcedure to analyze their data, in the present research Wetherington and Lucas' (1980) Fortran program, run on an Apple II computer, provided values of $\underline{k}$ and $\underline{re}$ and estimates of variance explained by the equation. This program implements a non-linear least-squares regression analysis. The method essentially consists of transforming the equation to a form expressed in

the *re* parameter, solving for *re* and using this result to determine *k*. An arbitrary starting value for *re* is chosen and this estimate is adjusted by an iterative numerical procedure to minimize the sum of squares of the residuals about the regression line. McDowell, (1981b) has found that the parameter and variance estimates provided by this method are identical to those given by Wilkinson's procedure to at least two decimal places.

Experiment I

This experiment constitutes a replication of Bradshaw's basic procedure and was undertaken to investigate the ability of Herrnstein's equation to describe the operant responding of human subjects.

Method

Subjects: Four female volunteers ranging in age from 20 to 34 participated. They were selected on the basis of their expressed desire for money (to ensure the efficacy of the reinforcers), experimental naivety and lack of previous training in psychology.

Setting and Apparatus: Experimental sessions took place in a sound-attenuated room. The participant sat at a table facing a sloping panel (height 24 cm., width 33 cm.). A button which provided auditory feedback when depressed with a force of approximately 16 N was mounted on the right of the panel, 14.5 cm. from the base. A counter was situated in the centre of the panel 9 cm. to the left of the button, and a blue light was set into the panel 6 cm. to the left of the counter. A rectangular panel (height 11.5 cm., width 40 cm.) was mounted on top of the response panel. On the rectangular panel were five red lights, 5 cm. apart, labelled 1 to 5 from left to right. A small sign above the counter read "1 point = 4 cents". Figure 1 illustrates the apparatus.

-- Insert Figure 1 about here --

Coulbourn programming equipment situated in a neighbouring sound-attenuated room controlled the operation of the panel and a Coulbourn printer recorded responses and reinforcers delivered.

For subjects TR and RB a radio was present which provided light background music. The radio was introduced in view of the first two subjects' complaints of boredom. (In Bradshaw's experiments a radio is always present to mask extraneous noise).

Procedure: Participants deposited their belongings, including watches, with the experimenter before entering the experimental room. The following instructions, essentially the same as those

used by Bradshaw, Szabadi and Bevan (1976b) were given:

> "This is a situation in which you can earn money. You earn money simply by pressing the button. Sometimes when you press the button the blue light will flash on. This means you will have earned a point worth 4 cents. The total amount of points you have earned is shown on this counter; (E. indicates the counter) every time the blue light flashes it adds one point to the total score.
>
> When operating the button make sure you press hard enough. You can tell whether you have pressed hard enough by listening for a click coming from inside the box.
>
> Now look at these red lights (E. indicates the schedule lights at the top of the panel). When one of the red lights is on, it means you are able to earn money. At the beginning of the session one of the lights will come on and will stay on for 10 minutes: throughout this time you can earn money. At the end of 10 minutes the light will go off for 5 minutes and during this time you should rest. After the rest period, another red light will come on, again for 10 minutes, and you may

earn some more money. Then there will be another rest period and so on until each of the five red lights has been presented. You can only earn money when one of these lights is on. When no light is on you should rest.

A buzzer will sound twice to signal the start of the session, and twice again to signal the end. Towards the end of each rest period, the buzzer will sound <u>once</u> as a signal that one of the red lights is about to come on.

At the end of the session, please remain seated and wait for the experimenter, who will note down from the counter the amount you have earned. You will be paid in a lump sum at the end of the experiment".

Each of the five red schedule lights was associated with a different RI schedule, providing reinforcement frequencies as follows:

#	Schedule	Rft./hr.
1	8 sec.	445
2	17 sec.	211
3	51 sec.	70
4	171 sec.	21
5	720 sec.	5

Reinforcement consisted of the delivery of one point to the counter accompanied by a brief flash of the blue light. The 5 schedules were presented in a quasi-random order with each schedule occuring in a different position on successive sessions. The 70 min. sessions took place on 15 consecutive days for subjects KR and AD and on 12 and 14 days for subjects TR and RB respectively.

Results

Figure 2 depicts the plot of response rate against reinforcement frequency for each subject for the last 3 sessions, with the fitted functions. It shows the values of k and r_e and an estimate of the variance explained by the equation for each subject's data averaged over the last three sessions. This final three session average is commonly used (e.g. Bradshaw, Szabadi & Bevan, 1977, 1978, 1979; Bradshaw, Szabadi, Bevan & Ruddle, 1979) and observation of subjects' performance over sessions indicated that responding was stable before this point. For 3 subjects, the equation accounts for greater than 75% of the data variance, although the fit for one subject, AD, is less adequate.

-- Insert Figure 2 about here --

The response rates of KR and AD show insensitivity to changes in rate of reinforcement. They responded about the same rate on all schedules. For TA and RB, discrimination among the schedules was more pronounced, as reflected in the greater curvature of

their functions, with response rate increasing with increase in reinforcement frequency. Note that the scale on the ordinate has been changed for RB to accommodate her very low rate of response

Estimates of response stability are presented in Table 2. The difference between response rate for each schedule averaged over the last block of 3 sessions and rate averaged over the proceeding block of 3 sessions is expressed as a percentage of the average rate for all 6 sessions (Sidman, 1961)

-- Insert Table 2 about here --

KR and AD were the most stable responders. For all schedules, their rates of response on the final 3 sessions are within 6% of the rates on the preceeding 3 sessions. TA and RB show far greater variability, particularly on the leaner schedules. Examination of day to day performance shows that this is not due to any systematic changes in rate, for example gradually reducing responding on leaner schedules, but rather to unpredictable fluctuations over sessions. However, for RB these fluctuations are, in absolute terms, minimal, but are magnified by the fact that she responded extremely slowly. For instance, her average rate of response on the leanest schedule for the last 3 sessions was 3.03 R/min. and for the preceeding block 3.77 R/min.

There is little clear indication of a gradually developing fit of the function to the data over the later sessions of the experiment. Sessions were grouped in consecutive blocks of 3 (i.e. sessions 1, 2 and 3; sessions 2, 3 and 4; sessions 3, 4 and 5 etc.) and the constants and percent variance explained was calculated for each block. Table 3 gives these results for each subject for that group of 3 sessions which provides the best fitting function.

-- Insert Table 3 about here --

Only for KR was the best fitting function found on the final 3 experimental sessions. However, this represents a somewhat sudden development. For the preceeding blocks of sessions the percent variance explained was much lower: sessions 10, 11, 12: 43%; sessions 11, 12, 13: 13%; sessions 12, 13, 14: 33%. Both AD and RB achieve their best fitting session block towards the end of the experiment, but while RB's data are well described by the equation from the fourth session on (over 80% of the variance explained), AD's are quite poorly described overall, with this better fit a somewhat isolated instance. This is due only in part to the fact that there was little variability in her responding across schedules, as the higher percentages of variance explained are not necessarily associated with the greater amounts of total variability found. TA, it will be recalled, ran for only 12 sessions, so her best fitting block occurs just into the second half of the experiment. Indeed, her final 3 session block exhibits

the poorest fit from that point (sessions 8, 9, 10: 92%; sessions 9, 10, 11: 92%; sessions 10, 11, 12: 75%).

Inter-subject differences in responding are evident. Two subjects, KR and TA responded at high rates, as reflected in their k values, AD responded at a moderate rate and RB at a very low rate. Although the highest k value obtained is associated with a very low re value (KR), and the lowest k with the highest re (RB), the values obtained by the two intermediate subjects do not indicate a clear cut inverse relationship between k and re. Considering in particular Table 3, it can be seen that the higher re values are obtained by the two subjects, TA and RB for whom the radio was present.

For the group of four subjects as a whole, delivered reinforcement rate was within 10% of scheduled reinforcement rate for schedules 1 to 3, and within 12% for schedule 4. On 5, the leanest schedule, delivered reinforcement rate was 40% of that scheduled. This large discrepancy can be accounted for by the fact that since the average number of reinforcers scheduled per hour was only 5, any deviation from this accounts for a greater percentage difference than would be the case given a richer schedule.

Post-experimental interviews were conducted with each subject to attempt to assess the influence of such factors as demand characteristics, control by instructions and subjects' response strategies. Copies of the interview questions and questionnaire items are shown in the Appendix. The interview and questionnaire data were not formally analyzed, as there was much variability

in subjects' responses. However, some generalizations are possible. None of the subjects reported forming or attempting to conform to any ideas as to the experimental hypothesis. The experimenter was rated as positive to neutral, and no subject indicated having been cued by the experimenter's behavior as to the manner in which she ought to perform. Neither KR nor AD, who both showed insensitivity to changes in reinforcement rate, could verbalize a discrimination among the schedule conditions. Both subjects maintained that the experiment was so boring that they pressed the button automatically while thinking of other things, which is consistent with the lack of differentiation in their responding. TA and RB were able to rank order the schedules appropriately in terms of frequency of point delivery and to give fairly accurate estimates of the number of points delivered by each schedule in a session.

Discussion

The equation describes responding for the subjects of this experiment somewhat less adequately than Bradshaw's results have indicated. In these experiments it is not uncommon to find well over 90% of the variance in responding explained by the equation. In the present experiment, however, the equation provides a less dramatic fit. Two of the subjects, KR and AD, showed insensitivity to variation in rate of reinforcement, reflected in very low r_e values and functions which rise steeply to asymptote. For KR, the function appears to fit the data adequately, in terms of the percentage of variance it explains (80%). However, in view of the

fact that her response rate was not responsive to reinforcement rate changes, there is relatively little data variance to be accounted for. The apparently "good" fit of the function is misleading, in that empirically, the relationship between her rate of responding and rate of obtained reinforcement is not hyperbolic in form.

In terms of the theoretical interpretation of the equation, the extremely low _re_ values obtained by KR and AD are consistent with the lack of stimulation in the environment. These are the subjects for whom the radio was not present, and indeed both complained of boredom and dissociation from the task. More adequate fits of the function, and higher _re_ values, were obtained by TA and RB, in the presence of the radio. The interpretation of _re_ as a parameter reflecting the operation of sources of reinforcement other than that directly contingent on the target behavior may be subjected to a more direct test. The superimposition of response-independent points on ongoing responding for contingent points, in the manner of the alternative reinforcement paradigm discussed previously, constitutes such a test. That contingent points function as reinforcers is indicated by the fact that they serve to maintain responding and that, at least in the case of TA and RB, response rate varies with alterations in reinforcement rate. It is reasonable to assume that the addition of response-independent points constitutes an alternative source of reinforcement which would influence the _re_ parameter of the equation and serve to decrease ongoing responding. The second experiment aims to test this hypothesis.

Experiment II

This experiment was designed to test the prediction from Herrnstein's equation of a decrease in response rate and an increase in *re* in the presence of response-independent reinforcement.

Method

Subjects: Four female volunteers in their 20s participated. All were experimentally naive, expressed a desire to earn money and had no prior training in behavioral psychology.

Setting and Apparatus: The same setting was employed as in Experiment I, but in order to increase the salience of the schedule lights the room was illuminated by a 150 watt lamp situated to the right of the subjects' panel. The radio was on throughout the experiment for all subjects. In addition to the main panel, a small box (height 13 cm, width 13.5 cm) with a counter in the centre and a red light situated above the counter was present (see Figure 1). During sessions when response-independent reinforcement was in effect, a sign placed above the light read "Free Points".

Procedure: The same instructions were given as in Experiment I, with slight changes in wording to accommodate the fact that 3 sessions occurred consecutively on the same day, with 10 min. rest breaks between them. Thus each subject attended for a total of 15 sessions held in blocks of 3 on 5 consecutive days. The inter-schedule rest period was shortened from 5 to 2 min. The

same schedules were in effect as in Experiment I. Both earned and free points were valued at 4 cents each, except for subject RM, for whom rate of delivery and point value were modified.

Immediately prior to the third session the following instructions were given:

> During this set of red lights, and during every alternate set from now on, as well as the points you earn on this counter (E. indicates the counter on the main panel) you will be given some free points, also worth 4 cents each. When this red light flashes and the beeper sounds (E. indicates the small box), a free point will appear on this counter.

During the alternate "free points" sessions response-independent points were delivered to the counter on the small auxiliary box during the presentation of each of the 5 response-dependent schedules. For subjects RB, GE and DN, response-independent reinforcement was delivered at the rate of 120 rft/hr., according to an RT 30 sec. schedule. For subject RM, this basic procedure was modified such that free points were valued at 1 cent, rather than 4 cents, and were delivered at the rate of 480 rft/hr. according to an RT 7.5 sec. schedule. So, for RM, response-independent points of a lower value were delivered at a higher rate than for the other 3 subjects. Total cash available per hour was, however, the same for all.

Results

Figure 3 shows the fitted functions for each subject for both re and non-re conditions with response rate plotted against reinforcement rate, for the last 3 sessions. Values of k and re and percentage of variance explained by the equation are also shown. Herrnstein's equation accounts for over 80% of the variance in responding in both conditions for all subjects with the exception of RM, for whom just under 65% of the variance is explained in the re condition.

-- Insert Figure 3 about here --

Within subjects, the form of the functions for the two conditions is very similar, although for GE the re function shows slightly more pronounced rectangularity. The predicted relationship between the functions, that is, with the re function lower and flatter than the non-re function but approaching the same asymptote, is approximated only in the case of RM, although her actual data are not as well described by the equation in the re condition. For the other three subjects, the re function lies above the non-re function and, except in the case of RB, appears to be approaching a different asymptote.

Table 4 shows response stability estimates. Since the introduction of response-independent reinforcement would be

expected to introduce instability into the data in the form of decreasing response rates, estimates are presented for the non-re sessions only. Responding is generally less stable than in the previous experiment, especially on the leaner schedules for RB, DN and RM (although in the case of RB this is more a function of low response rate, as differences in absolute rates are small), while GE responds in a less stable manner on the richer schedules.

-- Insert Table 4 about here --

This lack of stability cannot be accounted for entirely by the fact that the 3 sessions preceeding the final sessions are sessions 3, 4 and 5, so that subjects have had only 2 prior non-re exposures to the contingencies. Comparing sessions 5 and 6 with final sessions 7 and 8 does not substantially improve stability estimates and, as in the first experiment, inspection of day to day performance reveals that for the most part rate changes are unsystematic. Subjects DN and RM do, however, show a tendency to reduce responding over sessions on the leanest schedule.

Table 5 shows the values of the constants and variance explained for the block of 3 sessions on which the best fit to the function was obtained in each condition. In the non-re condition there is indication, in spite of daily response rate fluctuations, that adequate fits to the function are obtained from sessions 3, 4 and 5 on, and that a best fit does tend to develop over time. For 3 of the 4 subjects, the best fit was obtained on the final 3 session block.

-- Insert Table 5 about here --

As in the first experiment there are inter-subject differences in responding, with wide variation in the _k_ and _re_ values obtained. However, there is no clear indication of an inverse relationship between _k_ and _re_. Values of _k_ appear stable across conditions for RB and RM but not for GE and DN, contrary to Herrnstein's assertion. Considering the results for the final 3 sessions, as shown in Figure 3, substaintial differences in _re_ values between conditions are found for all subjects except DN, whose _re_ values are low in both conditions. Only for RM is the predicted increase in _re_ obtained on the final 3 sessions. In all other cases, the change is in the opposite direction to that predicted. That is, the _re_ value obtained is lower when response-independent reinforcement is present. However, when RM's best fitting functions for the two conditions are considered (Table 5) this increase is no longer apparent. The _re_ value obtained in the response-independent reinforcement condition is lower than that obtained in the absence of response-independent reinforcement.

According to the equation, the greatest decrease in responding should occur on the leaner schedules, where response-independent reinforcement constitutes the higher proportion of total reinforcement. To examine more closely the possibility of an effect of response-independent reinforcement on specific schedules which might not be evident from the _re_ values calculated on the basis of overall performance, suppression ratios were calculated on response rates averaged over the final 3 sessions of each

condition. Using the formula

$$re/(re + non\text{-}re)$$

suppression of responding the re condition is shown by ratios of less than 0.5. Facilitation of responding in the re condition results in ratios of greater than 0.5, while ratios around 0.5 indicate indifference between the two conditions. Suppression ratios are shown in Table 6.

-- Insert Table 6 about here --

There is some indication of decreased responding on the leanest schedule in the re condition for 3 of the 4 subjects for the last 3 sessions of each condition. However, comparing the 3 session blocks with the best fitting functions in each condition, this decrease is no longer evident, except for GE who achieved the best fitting functions on the final block.

All subjects could state a correct discrimination among the lights. Again, the experimenter was rated as positive to neutral and her behavior gave no cues to the expected performance. Subjects' ideas as to the purpose of the experiment were rather vaguely expressed, but generally included some reference to the effects of money on performance, although the free points were not specifically mentioned. No strong obligation to press the button was reported, and subjects attributed their continued pressing on the leaner schedules to the fact that they did not want to risk missing a point, and that they wondered if the schedules might change. Three of the subjects considered that

there might be a connection between their pressing and free point delivery, but were unclear as to whether this was really so and did not feel that it affected their performance. Only one subject, RM, mentioned the use of any particular response strategy. She concluded that the schedules were time based and tried to adjust her responding accordingly.

Discussion

Human responding on a simple operant task was adequately described by Herrnstein's equation. However, the prediction of a decrease in responding in the presence of response-independent reinforcement is not supported by the data. Except in the case of RM, values of *re* were found to be about the same or less in the response-independent reinforcement condition. Further, suppression ratios did not reveal the expected decrements in responding on leaner schedules. It therefore appears that, if anything, the presence of response-independent reinforcement served to facilitate rather than to suppress responding for ongoing contingent reinforcement. The only indication of support for the equation's prediction was obtained from RM, who, on the final 3 sessions of each condition, obtained a higher *re* value in the presence of response-independent reinforcement. However, in the *re* condition, the fit of her function is somewhat poor (66% variance explained), and when the best fit is considered, her *re* value is considerably lower. Since the fit of the function was on the whole better than in the first experiment, the failure

to observe the predicted response decrement cannot be attributed to a generally inadequate description of subjects' performance by the hyperbola.

The actual influence of subjects' suspicions as to a possible connection between their responding and the delivery of free points is difficult to determine, and the use of such relatively unsophisticated methods for assessing verbal control of behavior as post-experimental interviews does not allow any firm conclusions to be drawn. Nevertheless, a factor which might serve to influence responding is the discriminability of contingent and non-contingent points. Rachlin and Baum (1972) found that with pigeons the presentation of response-independent food led to lower rates of responding for response-dependent food, regardless of the cues distinguishing the two sources of reinforcement. However, if human subjects are given to attending to the possible effects of their responding on the delivery of response-independent reinforcement, obscuring the distinction between the two sources could lead to more pronounced response decrements. If the two sources are less readily discriminable, checking or observing responses could increase, competing with ongoing responding for contingent reinforcement. The third experiment includes a procedural variation of this nature.

Experiment III

As in the preceeding experiment, the aim was to test the prediction of a decrease in responding in the presence of response-independent reinforcement. This experiment removes the distinction between the two sources of reinforcement by delivering the free points, not to a separate counter, but to the same counter as the earned points and accompanying their delivery by the same discriminative stimulus.

Method

Subjects: Four female volunteers in their twenties participated, selected on the same bases as for previous experiments.

Setting and Apparatus: The same setting and apparatus were used as in Experiment II, but the auxilliary counter was removed and both free and earned points were delivered to the main counter.

Procedure: The same instructions were given and the same schedules used as in Experiment II.

At the beginning of the third session the following instructions were given:

> During this set of red lights, and during every alternate set from now on, as well as the points you normally earn by pressing the button, you will be given some free points. These free points are also worth

> 4 cents each. They will appear on the same counter, and are also signalled by the blue light. So, during the times when this sign is on the panel (E. indicates the "Free Points" sign) some of the points which appear on the counter will be points you earn by pressing the button, and some will be free points.

As in the previous experiment, both earned and free points were worth 4 cents each and free points were delivered according to an RT 30 sec. schedule during each of the five RI schedules. No special provision was made regarding priority of point delivery if both a response-dependent and a response-independent point became available at the same time. Tests indicated that on the richest schedule, RI 8 sec., with a steady response rate of 250 R/min. (machine simulated) such an overlap occurred only once during an hour.

Results

Figure 4 shows response rate plotted against delivered reinforcement rate for the final 3 sessions of the non-re and re conditions, for 3 subjects. The values of the constants and percentage of variance explained by the equation are also shown. For the fourth subject, ML, the equation provides a poor description of performance even on the non-re sessions (non-re: k = 43.06, re = 0.00, % variance explained <1%. re: k = 78.94, re = 4.30, % variance explained = 33.31). Her data cannot legitimately be

considered in evaluating the effects of response-independent reinforcement and are not presented in the Figure.

-- Insert Figure 4 about here --

For the final 3 sessions of the re condition, the fit of the equation is inadequate for 3 of the 4 subjects. Even for the best fitting 3 session block, as shown in Table 7, it is less than 80% for these 3 subjects, and especially poor for ML.

-- Insert Table 7 about here --

The insensitivity to changes in reinforcement rate shown by ML and CT is evident from the rectangularity of the functions, with most of the observed points around asymptote. This is similar to the data of KR and AD in the first experiment. For CT, the re function has the appearance of fitting the data well, although less than 1% of the variance is explained. This is attributable to the fact that there is little data variance to be accounted for. The expected relationship between the re and non-re functions is not obtained. Contrary to prediction, for all three subjects, the re function lies above the non-re function.

Stability estimates, shown in Table 8, indicate that while WL and CT show reasonably stable response rates, KT's responding is quite variable. This is shown, when considering the fit of the function in consecutive 3 session blocks, by the fact that in the non-re condition the variance explained was less than 25% for all blocks prior to the last.

-- Insert Table 8 about here --

However, in contrast to the other subjects, over 90% of KT's variance is explained for all blocks in the re condition. There was also a tendency for KT to decrease responding over sessions, especially on schedules 4 and 5. In general, for these subjects the fit of the function over consecutive 3 session blocks was considerably poorer than was the case in Experiment II, and there is again no good indication of a better fit developing gradually over time.

Higher k values do show some association with lower re values, but there is little indication of any close inverse relationship. Comparing the k values obtained by KT in her final and best fitting sessions, it can be seen that these are very similar. However, the corresponding re values are quite divergent. It therefore appears that certain k values can be associated with a wide range of re values. Values of k do differ somewhat across conditions for KT and WL, contrary to Herrnstein's assertions. Values of re do not show the predicted increase in the re condition.

Suppression ratios (Table 9) also indicate no consistent results. For KT, responding in the re condition is suppressed on schedule 5 but is also considerably elevated on the next leanest schedule. For WL and CT, slight elevation on the leanest schedule is indicated.

-- Insert Table 9 about here --

As in previous experiments, subjects rated the experimenter as positive to neutral and reported gaining no information from her

behavior regarding expected performance. Again, a connection between point delivery and responding was mentioned as being of probable interest to the experimenter but with no reference made to free points. Subjects did not report feeling constrained with regard to pressing the button, but reported continuing to do so on the leaner schedules for the same kinds of reasons as mentioned in the previous experiment -- unwillingness to risk missing points, thoughts that perhaps the schedules might change, and something to do to pass the time. KT and CT reported trying various counting strategies initially, but soon abandoning them when they did not appear to result in greater payoffs. KT and WL at first entertained the notion that free point delivery might be connected in some way to their pressing, and CT, although she believed that the free points really were free, reported that she pressed faster during free point sessions because "I could get more points then".

Discussion

The prediction of decreased responding in the presence of response-independent reinforcement is not supported by the results. This procedure, in which response-independent and response-dependent reinforcers are not associated with separate sources of delivery does, however, appear to have a more disruptive effect than the procedure used in Experiment II. This is shown by the fact that for two of the three subjects the equation provided a considerably poorer description of responding in the *re* condition.

Thus, removing the discriminative stimuli associated with the two sources of reinforcement did not influence the effectiveness of response-independent reinforcement inproducing decreased responding. Indeed, the relationship between the functions obtained in the re and non-re conditions suggests that, as in Experiment II, response-independent reinforcement has, if anything, an opposite effect to that predicted, although suppression ratios indicate that this is not a very strong or consistent effect.

As in the previous experiment, subjects reported at least some suspicion that the response-independent points might be related in some way to their pressing, but any effects of this on actual performance are difficult to determine. The reluctance to risk missing points by decreasing rate of responding noted in this and the previous experiment may relate to the use of a conditioned reinforcer, money, for which satiation may not readily occur. If subjects do perceive that the delivery of response-independent reinforcers is indeed contingent on their performance and tend to increase responding when free points are available, the use of a non-monetary source of alternative reinforcement should preclude this. This would also serve to test the interpretation of re as an index of the degree of contextual or background level reinforcement. As there is indication from the first experiment that the presence of a radio might influence the re parameter in the manner predicted by the equation, the fourth experiment uses a radio as a non-quantitative source of reinforcement.

Experiment IV

The purpose of this experiment was to exmaine the effect on responding of context or background level of reinforcement. A lower response rate in the presence of a higher level of background reinforcement is predicted.

Method

Subjects: Four female volunteers in their early twenties participated, selected according to the same criteria as used in previous experiments.

Setting and Apparatus: These were the same as for Experiment III, that is, only the main panel was present. Although speakers were present in the room at all times, the radio was only during each alternate session.

Procedure: The same instructions were given as in the first experiment, and the only amendment to the basic procedure was the presence/absence of the radio. This alternating procedure began after two initial sessions during which the radio was inoperative, and no instructions were given regarding its introduction.

Results

Figure 5 shows the plot of response rate against delivered reinforcement rate, with the fitted functions and values of the constants and variance explained for the final three sessions.

Except for SH, the functions obtained for the non-*re* and *re* conditions are similar in form. Again, the predicted relationship, with the *re* function lower and flatter, is not evident. For EN and JA the *re* function lies above the non-*re* function, while for DO and SH the relationship is less clearly defined.

-- Insert Figure 5 about here --

As in previous experiments, unsystematic changes in response rates are evident over sessions. The only obvious trend is shown by JA, who all but stopped responding on schedules 4 and 5 under both conditions, making only occasional responses at irregular intervals. Table 10 shows the constants and variance explained for these three sessions in each condition which provided the best fitting function.

-- Insert Table 10 about here --

Stability estimates are given in Table 11. In spite of the lack of consistency in responding over time, when consecutive 3 session blocks are considered, the equation describes the data well for all subjects. Over 90% of the variance is explained for all 3 session blocks for subjects DO and JA, over 80% for SH, except for *re* sessions 5, 6 and 7 (71%) and over 70% for EN, except for non-*re* sessions 7, 8 and 9 (60%) and *re* sessions 6, 7 and 8 and 7, 8 and 9 (26% and 32% respectively). As in the previous experiments, there is no gradually developing fit of the

function.

-- Insert Table 11 about here --

Inter-subject differences are evident, with high to moderate _k_ values and generally high _re_ values obtained in both conditions. Again, there is no indication of any systematic relationship between _k_ and _re_. When only the final 3 sessions are considered, thus comparing responding at about the same point in time, only DO shows a difference in _k_ values across conditions. The prediction of decreased responding with a higher level of background reinforcement is not supported. As can be seen from Figure 5, the _re_ value is higher in the _re_ condition for only one subject (DO), but this is not the case when her best fitting sessions are considered.

Suppression ratios, given in Table 12, show no consistent decrements in responding in the _re_ condition. Rather, contrary to prediction, a slight increase on the leanest schedule is indicated for all subjects.

-- Insert Table 12 about here --

Post experimental interview data are available only for JA and SH. Both mentioned the relationship between points earned and reinforcers delivered as being of probable interest to the experimenter, but only JA indicated the radio as an important variable. She suggested that the purpose of the experiment might be to determine "the benefits of playing music to people who have to perform menial tasks". She thought the music should have a "relaxing" influence, but did not state clearly any specific

effect this might be expected to have on performance. She did not feel that her own performance was significantly influenced by the radio. Se reported finding the radio sessions more enjoyable, and SH reported that "it wasn't as boring with the radio on". Both tried explicit counting strategies initially, but later abandoned them.

Discussion

Although Herrnstein's equation described subjects' responding, the increased environmental stimulation in the re condition was not associated with increased re values and decreased response rates. As in previous experiments, there was some tendency for re values to be lower in the re condition, and suppression ratios indicate a slight increase in responding on the leanest schedule. Thus, a manipulation of contextual or background reinforcement also failed to have the effects on responding predicted by the equation. This slight facilitatory effect on responding cannot be attributed to the use of a monetary reinforcer, and suggests that the similar results obtained in the previous two experiments may not be best understood in terms of subjects' vaguely expressed suspicions as to a connection between their pressing and free point delivery.

The nature of the extraneous reinforcement may be important in affecting responding. For instance, if magazines or a TV had been provided rather than a radio, response decrements might have been found. However, the radio was deliberately chosen because it

does not require the performance of any competing response, and is thus comparable in this respect to the delivery of response-independent points. It would be somewhat unremarkable if subjects were to decrease responding while engaging in some competing behavior such as reading a magazine. As indicated in the theoretical section, the equation predicts that extraneous reinforcement should influence responding whether or not it involves an explicit competing response. Although subjects reported post hoc that the radio sessions were more pleasurable, there was no other independent assessment of the reinforcing efficacy of radio music for these subjects. Perhaps the radio was simply a weak source of reinforcement. However, taken along with the results of the other experiments in this series, Experiment IV suggests that a reconsideration of the interpretation of the r_e parameter is warranted.

GENERAL DISCUSSION

The results of Experiments II to IV show that response-independent reinforcement failed to affect the re parameter of the equation in the manner predicted and did not lead to decreased responding for response-dependent reinforcement. This was so whether the alternative reinforcement was the same as that which was contingent on responding or non-discrete and qualitatively different. Indeed, over all experiments, whether the final or best fitting sessions are considered, there are more cases in which the value of the re parameter was greater in the condition where only response dependent reinforcement was obtained. By definition, re represents all sources of reinforcement other than that contingent on the target response, whether or not these alternative sources of reinforcement are conditional on other responses. Thus, the fact that the prediction of decreased responding in the presence of response-independent reinforcement was not supported indicates the necessity for a closer appraisal of the theoretical interpretation of the re parameter. Its failure to be affected in the predicted direction by the very operations which are said to define it indicates that there are constraints on its definition which require further consideration.

The process by which response-independent reinforcement affects behavior is not clearly specified. Herrnstein, as indicated in the theoretical section of the literature review, postulates that other behaviors, Re, are involved in the consumption

of reinforcement from alternative sources. This proposition is difficult to test. These other behaviors may not be visible or measurable, and indeed may be internal and affective (Herrnstein, 1970, 1974), serving to distract the organism in some way from the task. If *Re* cannot be measured then it can only be inferred from a decrease in the target response. The presence of these *Re* behaviors is a fundamental assumption of the theory and is not subject to disproof. If the predicted decrease does not occur, then, within the framework of the theory, one is forced to conclude that the alternative source of reinforcement failed to activate the hypothetical *Re* behaviors, rather than to question the theoretical status of such responses. Similarly, the definition of *re* as all other sources of reinforcement, which are consumed by *Re*, is basic to Herrnstein's theory of the single operant. Within the theory, therefore, one cannot draw the conclusion that *re* does *not* reflect the operation of other sources of reinforcement. Rather, one must conclude that the conditions under which these alternative sources of reinforcement affect the *re* parameter, and the ways in which it is affected, are subject to constraints. Only when such constraints are specified by further research can an adequate understanding of the theoretical nature of the *re* parameter be attained.

Herrnstein's account does not specify any limitations on the capacity of alternative sources of reinforcement to affect target responding, yet it seems readily apparent that such limitations must exist. For example, the relationship between

the target behavior and alternative reinforcement may be important. For example, one could observe, a group of preschoolers, select a different target behavior for each, and then introduce some stimulus with predetermined reinforcing efficacy into the setting on a response-independent basis. The equation as it now stands would predict a decrease in the frequency of each of these target behaviors. However, if the response-independent reinforcer was candy, and the target response happened to be smiling or jumping up and down, these behaviors might well show an increase in the presence of response-independent reinforcement. Indeed, there is some indication from the present research of increased responding in the presence of response-independent reinforcement. The definition of r_e as representing background level of reinforcement seems particularly subject to constraint. The final experiment in the present series indicated increased responding on the leaner schedules during sessions when the radio was present, and examples of situations in which music appears to facilitate behavior are apparent. For instance, Konz (Note 3) found that background music facilated the performance of manual assembly tasks and enhanced productivity.

As well as the relationship between the target response and alternative reinforcement, the relationship between contingent and non-contingent reinforcement is also a possible limiting factor. Some research with conventional concurrent schedules indicates a breakdown of the matching relationship when qualitatively different reinforcers are used (see de Villiers, 1977).

The issue of the substitutability of reinforcers is currently receiving attention from an economic-behavioral perspective (Rachlin, Kagel & Battalio, 1980). The single operant equation, as a derivation from the matching relation, is no doubt subject to similar constraints.

Not only does the present research indicate the need for further understanding of the operations that control the <u>re</u> parameter, it also lends some support to criticisms of quantitative approaches to the study of operant behavior. Following in the footsteps of Skinner (1953, 1959), Catania (1981) has argued that reliance on mathematical descriptions of behavior may distract attention from the actual data and possibly generate misleading conclusions. An instance of this is found in the present research for subjects whose response rate did not vary with changes in reinforcement rate. In Experiment I, for example, the equation accounted for 80% of the variance in subject KR's responding, which is an apparently adequate description of the data. However, it is evident that there is in fact no empirical relationship between rate of reinforcement and rate of response for this subject. In this case, the theory represented by the equation seemingly misrepresents the actual data. Once the data are "found" to be described by the equation, the lack of variation in response rate with changes in the reinforcement rate may be explained by concluding that KR is responding "at asymptote". Such a conclusion implies that the equation "really" describes her responding and were, for instance, the force requirement on the button to be increased,

or the value of the VI changed, this would become evident (McDowell, Note 1). Certainly, an alteration in the experimental conditions could be expected to produce behavior changes. However, it would seem more profitable to direct research attention explicitly to discovering the conditions under which the equation does, or does not, describe responding, rather than to "revealing" the relationship predicted by the equation. As Catania (1981) points out, "the laboratory behavior occasioned by questions about whether a particular law is correct or true is likely to be different from that occasioned by questions about whether particular variables affect behavior in particular contexts" (1981, p. 49).

The present research indicates the necessity for further investigation of the variables which affect the <u>re</u> parameter at the level of basic research with human subjects. It must therefore be concluded that McDowell's (1981a, 1982) application of the equation to therapeutic intervention strategies is somewhat premature. Before the effects of such factors as relationships among qualitatively different sources of reinforcement, or the relationship between the target response and other sources of reinforcement are clarified, attempts at application may prove unproductive. For example, in applied settings, increasing background level of reinforcement in order to decrease responding is somewhat counterintuitive and contrary to generally accepted therapeutic practice. The principle followed in inpatient rehabilitation programs is generally to increase background level of stimulation. A more pleasant environment is created by decorating walls with pictures, providing music, TV, etc., in order to counter

"institutionalization", which in behavioral terms may be characterized as a condition of low rate responding. Horner (1980) studied the effects of "enriching" the environment of profoundly retarded children with toys and objects on four categories of maladaptive behavior. He concluded that the provision of toys alone, even without differential reinforcement for their use, was effective in both increasing adaptive play and in reducing maladaptive behavior. However, the effect was mainly on self-directed and object-directed maladaptive behavior and not on adult- and child-directed maladaptive behavior. Since Herrnstein's equation does not specify what operations will function as <u>re</u> for what particular behaviors, it cannot deal with differential effects of other sources of reinforcement on behavior. As it now stands, the theory could neither predict nor account for the results of an experiment such as Horner's.

Although the results of Bradshaw's series of studies indicate that the behavior of human subjects on a simple operant task is at least as well described as the behavior of infra-humans on similar types of task, the present research suggests some considerations peculiar to the use of humans as subjects. Five out of 16 subjects showed relative insensitivity to changes in rate of reinforcement in the non-<u>re</u> condition, reflected in low values of <u>re</u> and functions with a small region of curvature. Bradshaw (Note 4) found no variability in response rate as a function of changes in reinforcement for 4 out of about 40 subjectes tested, all of whom were atypical in some respect. Two were tested on a lever pulling task, and two were psychiatric patients. As well,

JL, 1977; CW, 1978: and BB, 1979 (see Table 1) show rather low re values, but not as low as those found in the present research. Wearden, Lochery and Oliphant (note 2), however, also found re values below 1 for 2 of their 8 subjects (JL and JA; see Table 1). Such lack of control of behavior by the reinforcement contingencies raises the question of what other factors might serve to influence subjects' responding. Control by instructions has been noted as a possible source of interference with contingency control in human operant research (e.g. Baron, Kaufman & Stauber, 1969; Galizio, 1979; Shimoff, Catania & Matthews, 1981). The instructions given, identical in all important respects to those used by Bradshaw, specified only the operating instructions for the panel and general experimental procedures, and the fact that so few of Bradshaw's subjects show insensitivity mitigates against an explanation in terms of control by instructions per se. Indeed, Wearden et al explicitly informed two of their subjects of the contingencies, and one of these, JA, still showed insensitivity. The influence of demand characteristics and subjects' self-generated response strategies cannot be discounted, but is difficult to assess from the information elicited on post-experimental interview. Only RM in Experiment II reported consistent use of a strategy, and most subjects said that they abandoned attempts at strategy after the initial sessions. Assessment of the effects of strategies on actual responding on the basis of post-experimental interview is likely to be unreliable and subject to distortion. Subjects may not be able to recall what they did, or may in retrospect

report use of strategies based on recall of their behavior, or may report use of strategies which appear to bear no relationship to what they actually did. A procedure in which subjects record their hypotheses and strategies, if any, as they perform might elicit more useful information (Catania, Shimoff & Matthews, Note 5).

As for experimental demands, some subjects reported feeling obligated to continue responding as they were "here to press buttons", while others reported feeling free to press or not press as they wished, and some preferred to press because it helped to pass the time, they did not wish to risk missing points, or they suspected that the schedules might change. It might be suggested that the use of money, a conditioned reinforcer on which subjects may not readily satiate, could serve to maintain responding at high rates regardless of the presence of response-independent reinforcement. However, this is not necessarily so, as witnessed by JA's (Experiment IV) comment that it was not worth the effort to respond on leaner schedules for only a few cents, and by the fact that when a decrease on leaner schedules did occur, it occurred on both non-re and re sessions (e.g. KT, Experiment III). The button pressing response was effortful and occasioned complaints of sore hands, arm tiredness, etc., so that it is unlikely that ease of responding was a factor in maintaining rate on leaner schedules. Indeed, such factors as outlined cannot account for the tendency of subjects to increase responding in the re condition; a result which is directly contrary to Herrnstein's predictions. It might, be argued that the receipt of additional points in the

free points sessions could serve to prime increased responding, as exemplified by CT's (Experiment III) comment that she pressed faster because she could get more points then, on the basis of a "moral" imperative - more money merits more work. However, the tendency to increased responding during re sessions was also evident in Experiment IV, when no additional money was received.

Some subjects clearly found the experiment very tedious. The task employed, while allowing response data to be readily and concisely measured and collected, is basically an adaptation to human subjects of the typical pecking or lever pressing task used with animals. The object of choosing such a simple task is of course to allow the operation of basic behavioral principles to be easily discerned. However, a task adapted from animal research may fail in this respect, if it does not engage the human participant sufficiently to minimize the influence of other factors such as boredom and experimental demands. Perhaps in adaptation of a video game, such as that employed by Baum (1975), with hits on alien invaders as reinforcers, would better fulfil these requirements.

The problem of stability of responding is particularly acute with human subjects. While Bradshaw and his colleagues typically report the development of stable responding by the fifth to the eighth session, as judged from cumulative records, Wearden et al (Note 2) found no indication of stability by the tenth and final session. Subjects' rate of response varied in an unpredictable fashion across sessions, and the researchers report quite extreme

fluctuations in the adequacy of the fit of the equation from day to day. Such variability indicates that the relationship between response rate and rate of reinforcement does not show a gradual development toward conformity with the function. In the non-re conditions of the present experiment, only 6 of the subjects achieved the best fit of the function on the final 3 sessions, and while for some subjects the function came to describe the data better over time, for others this was not the case. Unlike animals, control over human subjects' between-session experiences is not possible, and these may play some part in determining response stability. In the present series of experiments, such measures as were practical were taken to minimize the effects of extra-session variables. Subjects were run at the same time daily, and in the latter three experiments they attended each day for a block of three sessions. It is difficult to induce human subjects to agree to participate in an experiment for an unspecified number of sessions, until stable responding is observed. Some subjects were asked if they would continue for further sessions, but none agreed. The problem of drop-outs was at least solved by requiring a contractual agreement, with the money gained to be paid on completion of all sessions. However, given the fact that in most cases the best fit of the function was obtained at some point before the final sessions, duration of exposure to the schedule contingencies may not be the major factor in determining the fit of the function to the data. Furthermore, stability of responding per se does not guarantee a good fit of the function, as shown by subjects such as AD

(Experiment I) whose responding was very stable but not differentiated among the schedules.

There are methodological differences among the studies of Bradshaw, Wearden and myself. For example, the apparatus used by Wearden is smaller than that employed by Bradshaw, and on my apparatus the response button is located on the slope of the panel rather than on a flat surface. The monetary value of the reinforcers used in this study may differ from those of the two British studies. Although Wearden's schedules provide a wide range of reinforcement rates, they differ from those used by Bradshaw, and the present study employs RI rather than VI schedules.

Throughout this series of experiments, delivered reinforcement rate shows a systematic deviation from scheduled reinforcement rate. For all subjects over all non-re conditions, in which only the basic schedules were in effect, delivered reinforcement rate was within 10% of scheduled reinforcement rate for schedules 1 to 4, and within 25% for schedule 5. On all schedules, fewer reinforcers were due to the use of RI schedules as well as to slow-responding subjects. Tape-programmed VI schedules have the range of possible intervals predetermined by the experimenter, so that the longest interval which may elapse between opportunities for reinforcement is set at some maximum value. The RI schedules used in this experiment were programmed using Coulbourn modules with a probability of 25% that a reinforcer would be set up for delivery, given a response. Over the short run of 10 min. of schedule presentation per session it is possible that a series

of intervals could pass consecutively before a reinforcer was made available. This could create effectively longer inter-reinforcement intervals than would occur on an equivalent VI with an upper limit set on the size of the interval. However, the fact that reinforcers delivered were less than reinforcers scheduled does not mitigate against obtaining a fit to Herrnstein's function. This is the case because all schedules show this discrepancy and the progression from rich to lean is not altered. In fact, the sparseness of reinforcement on schedule 5 should operate in favor of the hyperbolic function (McDowell, Note 1).

As Wearden and his colleagues note, to attribute differences in findings between studies merely to relatively minor procedural variations is to suggest that conformity to Herrnstein's equation is a less than robust effect, subject to ready disruption. The results of animal experiments indicate that Herrnstein's equation does describe responding over a wide range of experimental procedures. The ability of the equation to describe operant responding in humans may well, on closer examination, turn out to be less adequate than has been shown to be the case for animals, but explanations for this may be sought in terms other than procedural nuances. The special characteristics of humans as subjects, and the theoretical nature of the equation appear to constitute more profitable foci of attention in explaining non-conformity. With regard to the present research, the fact remains that even for those subjects whose responding did conform to the equation, the predictions regarding the effects of response-independent reinforcement on responding and on the r_e parameter were not supported.

Wearden, Lochery & Oliphant (Note 2) indicated a possible inverse relationship between _k_ and _re_ in their data, and suggested that the same may be true for the experiments of Bradshaw et al. Such a relationship would be in line with other formulations of the quantitative Law of Effect which predict systematic changes in _k_ as a function of changes in the parameters of reinforcement (Staddon, 1977; McDowell & Kessel, 1979; McDowell, 1980). This is directly contrary to Herrnstein's assertion that _k_ should vary only with changes in response topography. Across experiments in the present research, no correlation was found between _k_ and _re_ in either non-_re_ ($r = -0.168$, $p < .05$, N.S.) or _re_ sessions ($r = 0.194$, $p < .05$, N.S.). In the experiment by Wearden et al, as in the present series, a wider range of _re_ values is reported then by Bradshaw et al. (see Table 1). Values of over 100 were reported by Wearden et al for two subjects, GR and AN, and in the present research are found for three subjects, GE (Experiment II), KT (Experiment III) and DO (Experiment IV) in the non-_re_ sessions and for DO in the _re_ sessions also. The _re_ values found for DO are extremely high, over 200 in both cases. Omitting the data for this outlying subject, negative, but non-significant correlations are found in both the non-_re_ ($r = -0.376$, $p < .05$, N.S.) and _re_ conditions ($r = -0.423$). Thus, no systematic association is found between _k_ and _re_, as Herrnstein predicts, although the tendency is towards an inverse relationship.

In conclusion, this research constitutes an initial attempt to sepcify the kinds of operations which affect the _re_ parameter of Herrnstein's equation. The results suggest that the current

understanding of _re_ as all sources of reinforcement other than that contingent on the target response is subject to constraint. Further research is required to specify these constraints and to provide an empirical basis for interpreting the meaning of the _re_ parameter. Such research can perhaps best be conducted by the use of experimental procedures more appropriate for evaluating the operant behavior of human participants. As Herrnstein's single operant theory appears to have limitations, especially when applied to humans, McDowell's extension of the equation to applied settings must be viewed as premature. Until the operation of the _re_ parameter is clarified at the level of basic human research, a practical technology based on the quantitative Law of Effect will remain only a possibility for the future.

FOOTNOTES

[1] Technically, a reinforcer is defined in terms of its operation as part of a contengency, and its effect in increasing behavior. As a "free" reinforcer may possess neither property, it may be argued that this term is a misnomer. However, following accepted usage in the literature, the terms response-independent, non-contingent and free reinforcement are used interchangeably here to donte the delivery of a positive stimulus according to a time schedule (Zelier, 1967) without reference to any specific behavior of the organism.

[2] It should be noted that while Herrnstein's equation is generally assumed to apply to steady-state behavior, Herrnstein (1979) suggests that it is also valid for responding during acquisition.

[3] A constant probability schedule is one in which time since the last reinforcer and probability of subsequent reinforcement are minimally related so as to prevent the inter-reinforcement interval from acquiring response-cueing properties. The RI schedule is a form of constant probability schedule in which reinforcement becomes available after the passage of each interval with fixed length, T, with probably, P. The mean inter-reinforcement interval is given by T/P. Thus, as P approaches 1.0, the RI schedule will approximate an FI and as P decreases a VI schedule is approximated. In the present study the schedules were created by varying T while holding P constant at 0.25.

Table 1

Values of the constants and variance explained by Herrnstein's equation. From Bradshaw, Szabadi & Bevan, selected experiments, and Wearden, Lochery & Oliphant (Note 2)

Bradshaw et al.

	Subject	k	re	% variance explained
1976b	BH	391.9	9.8	98
	BF	399.2	6.8	96
	SM	270.9	5.8	97
	AM	286.8	7.6	99
1977	BJ	139.3	16.8	97
	JL	102.5	1.3	99
	VG	218.8	13.8	99
1978	CW	299.8	1.4	92
	JC	81.6	14.2	96
	HB	86.9	2.7	89
	KD	294.8	67.7	99
1979	BB	251.1	1.9	88
	LK	275.0	3.6	88
	MS	291.6	8.6	98

Wearden et al.

	Subject	k	re	% variance explained
	AN	46.6	90.15	65
	JD	76.46	14.69	86
	JL	83.3	0.93	37
	GL	193.19	2.08	54
	AD	203.48	2.53	92
	GR	22.64	121.12	90
	LN	25.02	50.73	89
	JA	128.3	0.67	39

Table 2

Experiment I:

Response stability estimates. Difference between the average rate of responding on the final 3 sessions and average rate on the preceeding 3 sessions, expressed as a percentage of the average rate for all 6 sessions.

Subject	Schedule: 1	2	3	4	5
KR	5.76%	0.11%	2.54%	6.48%	1.81%
AD	5.05%	4.12%	3.09%	1.80%	2.34%
TA	0.67%	7.45%	8.85%	34.12%	52.32%
RB	0.44%	20.02%	20.37%	8.89%	21.76%

Table 3

Experiment I:

Estimated values of the constants and percentage of variance explained by the equation. Best-fitting 3 session blocks (Highest % variance explained).

Subject	Sessions	k	re	% variance explained
KR	13,14,15	243.11	0.21	80.16
AD	11,12,13	94.87	0.18	67.01
TA	7, 8, 9	226.30	23.64	96.33
RB	11,12,13	19.05	84.02	92.74

Table 4

Experiment II:

Response stability estimates. Difference between the average rate of responding on the final 3 sessions and average rate on the preceeding 3 sessions, expressed as a percentage of the average rate for all 6 sessions. Non-*re* sessions.

Subject	Schedule: 1	2	3	4	5
RB	0.29%	7.61%	3.11%	47.97%	25.50%
GE	53.01%	82.24%	7.63%	11.38%	2.27%
DN	12.87%	12.44%	13.31%	27.65%	11.19%
RM	18.46%	11.71%	17.86%	25.56%	67.31%

Table 5

Experiment II:

Estimated values of the constants and percentage of variance explained by the equation. Best fitting 3 session blocks. (Highest % variance explained).

	non-re sessions				re sessions			
Subject	sessions	k	re	% variance explained	Sessions	k	re	% variance explained
RB	6,7,8	12.07	81.42	83.85	3,4,5	13.70	83.07	86.72
GE	6,7,8	139.43	174.23	87.11	5,6,7	114.91	83.89	96.17
DN	5,6,7	238.43	1.98	91.08	4,5,6	249.71	1.40	91.87
RM	6,7,8	90.82	9.65	97.30	4,5,6	92.38	3.86	85.17

Table 6

Experiment II:

Suppression ratios. The ratio of average re response rate to average re response rate plus average non-re response rate. Final 3 sessions.

Subject	Schedule: 1	2	3	4	5
RB	.51	.51	.56	.63	.43
GE	.48	.52	.56	.50	.40
DN	.51	.51	.53	.55	.64
RM	.51	.51	.36	.48	.43

Table 7.

Experiment III:

Estimated values of the constants and percentage of variance explained by the equation. Best fitting 3 session blocks. (Highest % variance explained).

	non-re sessions				re sessions			
Subject	sessions	k	re	% variance explained	sessions	k	re	% variance explained
KT	6,7,8	94.96	138.96	86.98	4,5,6	79.37	39.61	99.59
ML	6,7,8	51.17	13.15	70.97	4,5,6	32.92	1.69	53.80
WL	8,9,10	142.64	1.48	85.64	3,4,5	132.58	1.35	77.85
CT	7,8,9	182.64	1.70	91.20	4,5,6	185.45	0.64	76.64

Table 8

Experiment III:

Response stability estimates. Difference between the average rate of responding on the final 3 sessions and average rate on the preceeding 3 sessions, expressed as a percentage of the average rate for all 6 sessions. Non-re sessions.

Subject	Schedule: 1	2	3	4	5
KT	35.30%	47.17%	105.64%	169.35%	121.05%
WL	0.50%	3.61%	9.97%	13.09%	1.73%
CT	3.78%	3.65%	0.78%	0.54%	5.55%

Table 9

Experiment III:

Suppression ratios. The raio of average *re* responses rate to average *re* response rate plus average non-*re* response rate. Final 3 sessions.

Subject	Schedule: 1	2	3	4	5
KT	.51	.49	.54	.80	.13
WL	.53	.54	.52	.50	.57
CT	.50	.51	.50	.52	.55

Table 10

Experiment IV:

Estimated values of the constants and percentage of variance explained by the equation. Best fitting 3 session blocks (Highest % variance explained).

	non-re sessions				re sessions			
Subject	sessions	k	re	% variance explained	sessions	k	re	% variance explained
DO	7,8,9	169.88	214.44	99.37	4,5,6	90.34	104.41	98.93
EN	4,5,6	51.69	20.12	88.64	3.4.5	55.51	25.08	82.73
JA	8,9,10	203.41	26.44	99.44	3,4,5	204.18	10.72	99.44
SH	3,4,5	225.70	64.48	99.47	3,4,5	280.09	69.03	94.02

Table 11

Experiment IV:

Response stability estimates. Difference between the average rate of responding on the final 3 sessions and average rate on the preceeding 3 sessions, expressed as a percentage of the average rate for all 6 sessions. Non-*re* sessions.

Subject \ Schedule:	1	2	3	4	5
DO	24.52%	51.92%	11.66%	102.02%	57.53%
EN	23.71%	25.57%	3.09%	23.03%	32.46%
JA	5.10%	4.49%	13.95%	192.70%	83.65%
SH	3.70%	2.50%	15.39%	17.21%	28.08%

Table 12

Experiment IV:

Suppression ratios. The ratio of average _re_ response rate to average _re_ response rate plus average non-_re_ response rate. Final 3 sessions.

Subject	Schedule: 1	2	3	4	5
DO	.53	.53	.40	.44	.56
EN	.56	.55	.52	.54	.59
JA	.49	.50	.55	.81	.53
SH	.48	.51	.54	.51	.67

FIGURE CAPTIONS

Figure 1. Subject response panel.

Figure 2. Experiment I. Response rates as a function of delivered reinforcement rates for four subjects. Points are mean response rates for the last three sessions. Curves represent the best fit of Herrnstein's equation to these points. Also shown are the subject identifier (eg. KR), the values of the equation parameters (_k_ in responses per minute, and _re_ in reinforcers per hour) and the percentage of variance explained by the equation.

Figure 3. Experiment II. Response rates as a function of delivered reinforcement rates for four subjects. Closed circles are the mean response rates for the last three non-_re_ sessions, and open circles are the mean response rates for the last three _re_ sessions. Solid curves represent the best fit of Herrnstein's equation to the non-_re_ session data, and broken curves represent the best fit to the _re_ session data. The values of the equation parameters, _k_ and _re_, and percentage of variance explained are shown for both non-_re_ and _re_ sessions.

Figure 4. Experiment III. Response rates as a function of delivered reinforcement rates for three subjects. Details same as for Figure 3.

Figure 5. Experiment IV. Response rates as a function of delivered reinforcement rates for four subjects. Details same as for Figures 3 and 4.

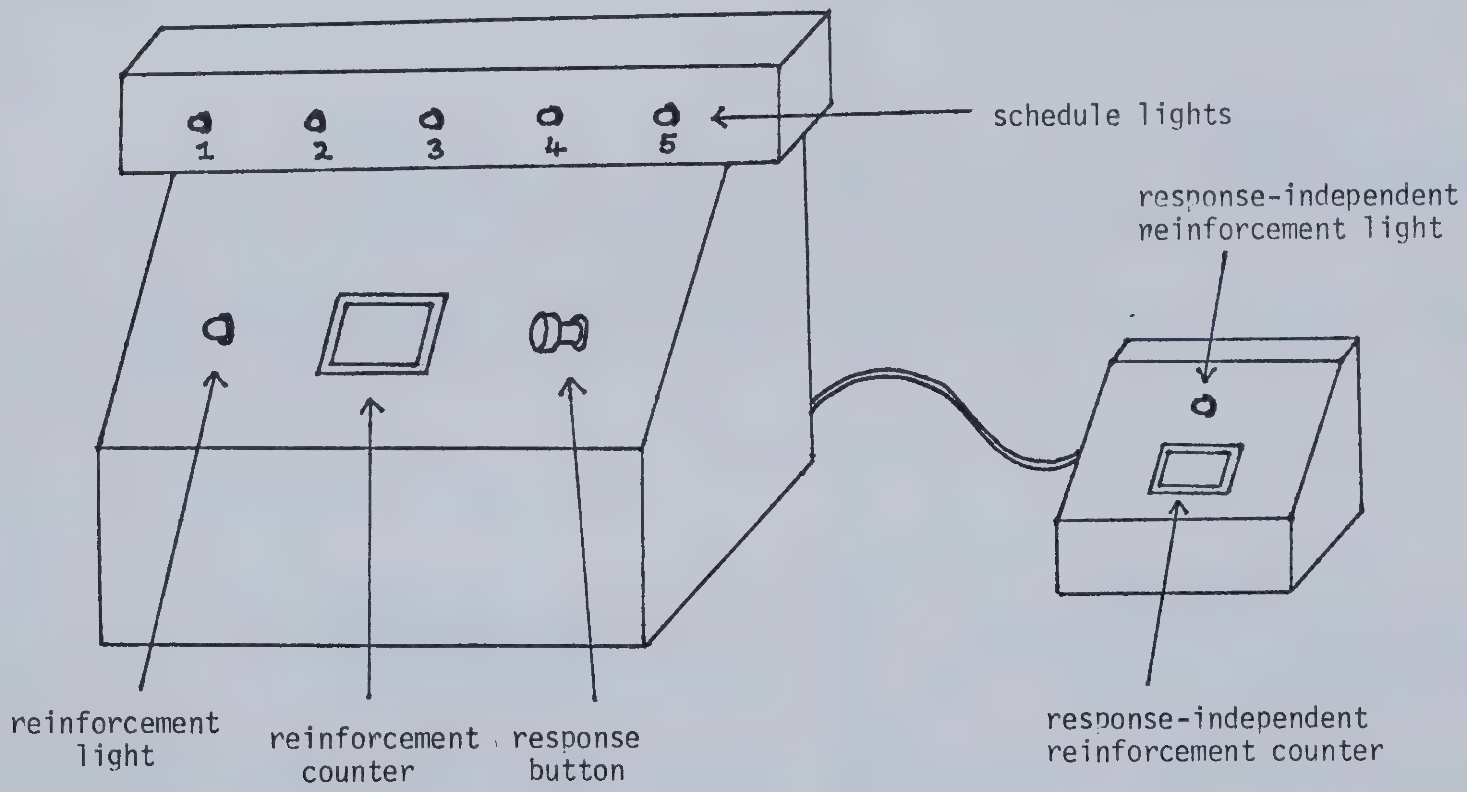

1
2
3
4
5
schedule lights
response-independent reinforcement light
reinforcement light
reinforcement counter
response button
response-independent reinforcement counter

Figure 1

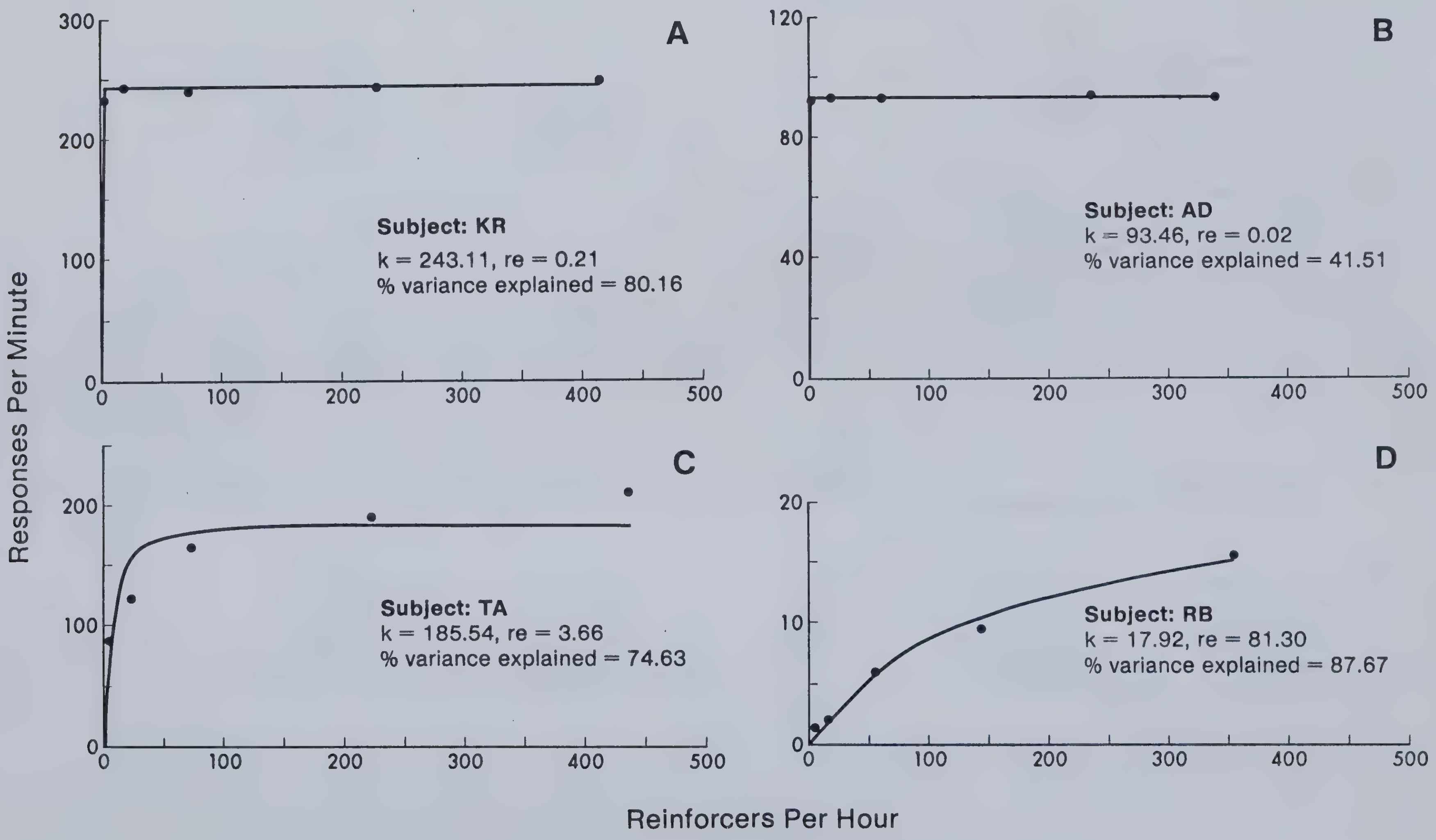
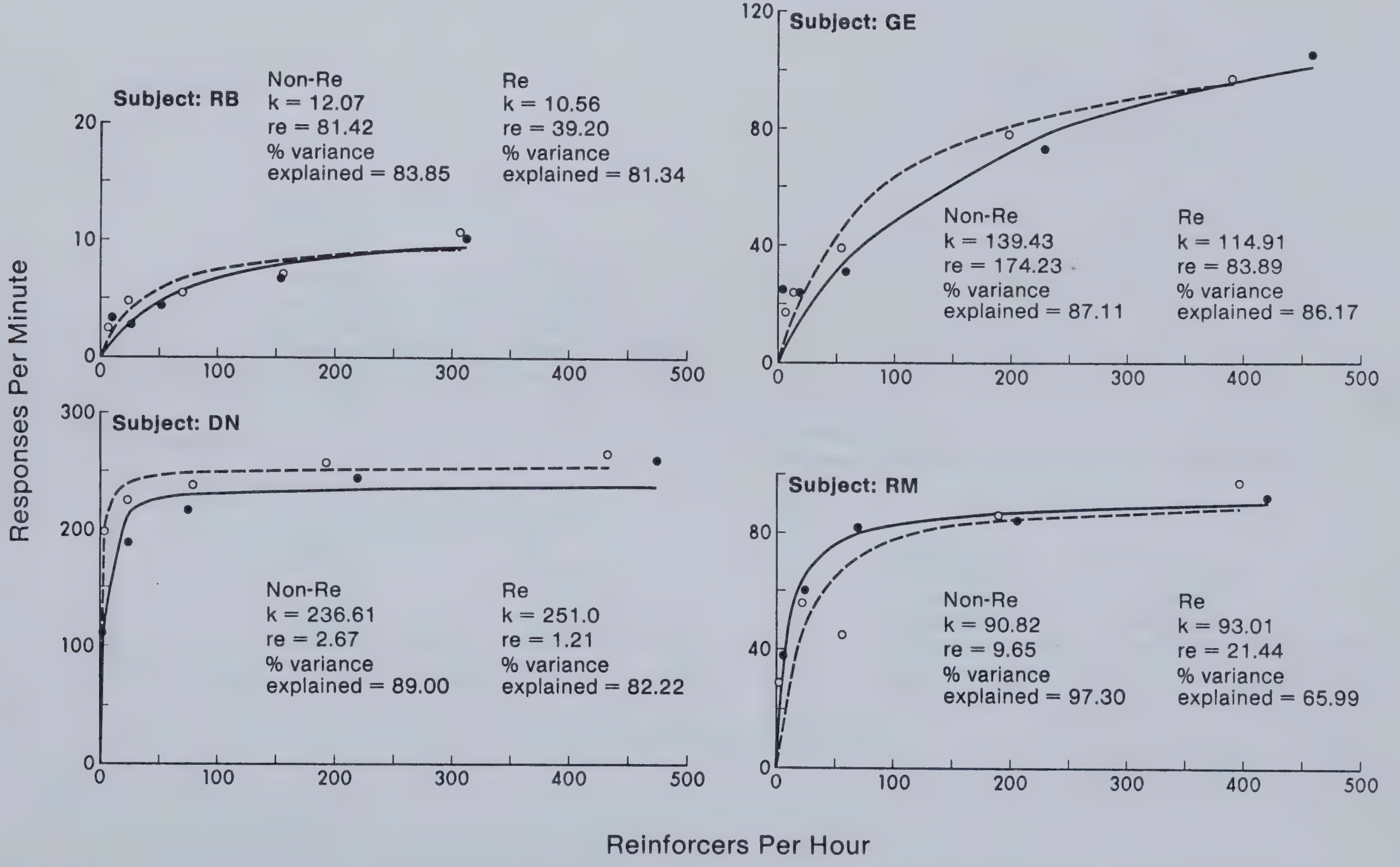

A
Subject: KR
k = 243.11, re = 0.21
% variance explained = 80.16
B
Subject: AD
k = 93.46, re = 0.02
% variance explained = 41.51
C
Subject: TA
k = 185.54, re = 3.66
% variance explained = 74.63
D
Subject: RB
k = 17.92, re = 81.30
% variance explained = 87.67
Responses Per Minute
Reinforcers Per Hour

Figure 2



Subject: RB
Non-Re
k = 12.07
re = 81.42
% variance
explained = 83.85
Re
k = 10.56
re = 39.20
% variance
explained = 81.34
Subject: GE
Non-Re
k = 139.43
re = 174.23
% variance
explained = 87.11
Re
k = 114.91
re = 83.89
% variance
explained = 86.17
Subject: DN
Non-Re
k = 236.61
re = 2.67
% variance
explained = 89.00
Re
k = 251.0
re = 1.21
% variance
explained = 82.22
Subject: RM
Non-Re
k = 90.82
re = 9.65
% variance
explained = 97.30
Re
k = 93.01
re = 21.44
% variance
explained = 65.99
Responses Per Minute
Reinforcers Per Hour

Figure 3

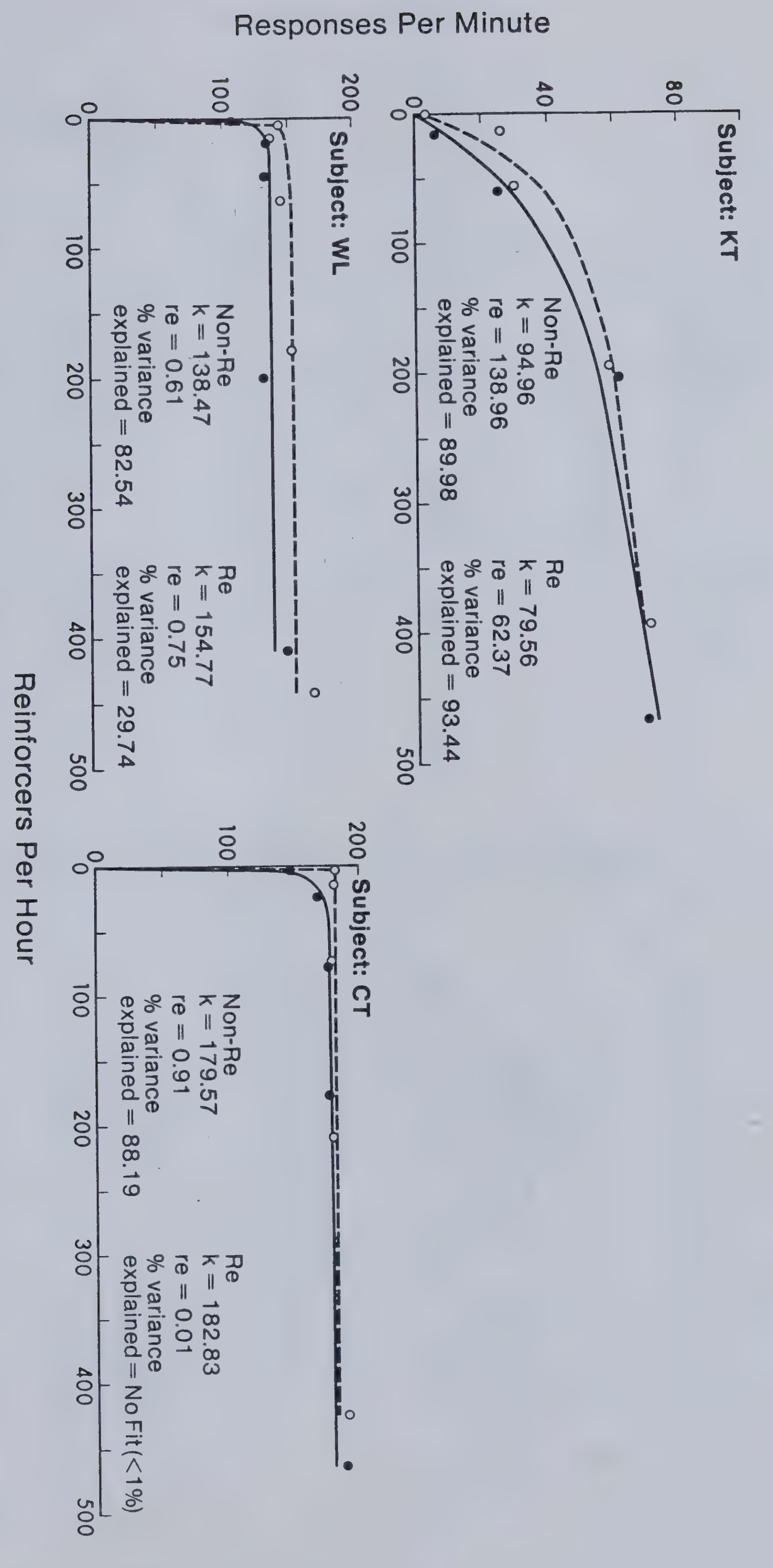

Responses Per Minute
Reinforcers Per Hour
Subject: KT
Non-Re
k = 94.96
re = 138.96
% variance
explained = 89.98
Re
k = 79.56
re = 62.37
% variance
explained = 93.44
Subject: WL
Non-Re
k = 138.47
re = 0.61
% variance
explained = 82.54
Re
k = 154.77
re = 0.75
% variance
explained = 29.74
Subject: CT
Non-Re
k = 179.57
re = 0.91
% variance
explained = 88.19
Re
k = 182.83
re = 0.01
% variance
explained = No Fit (<1%)

Figure 4

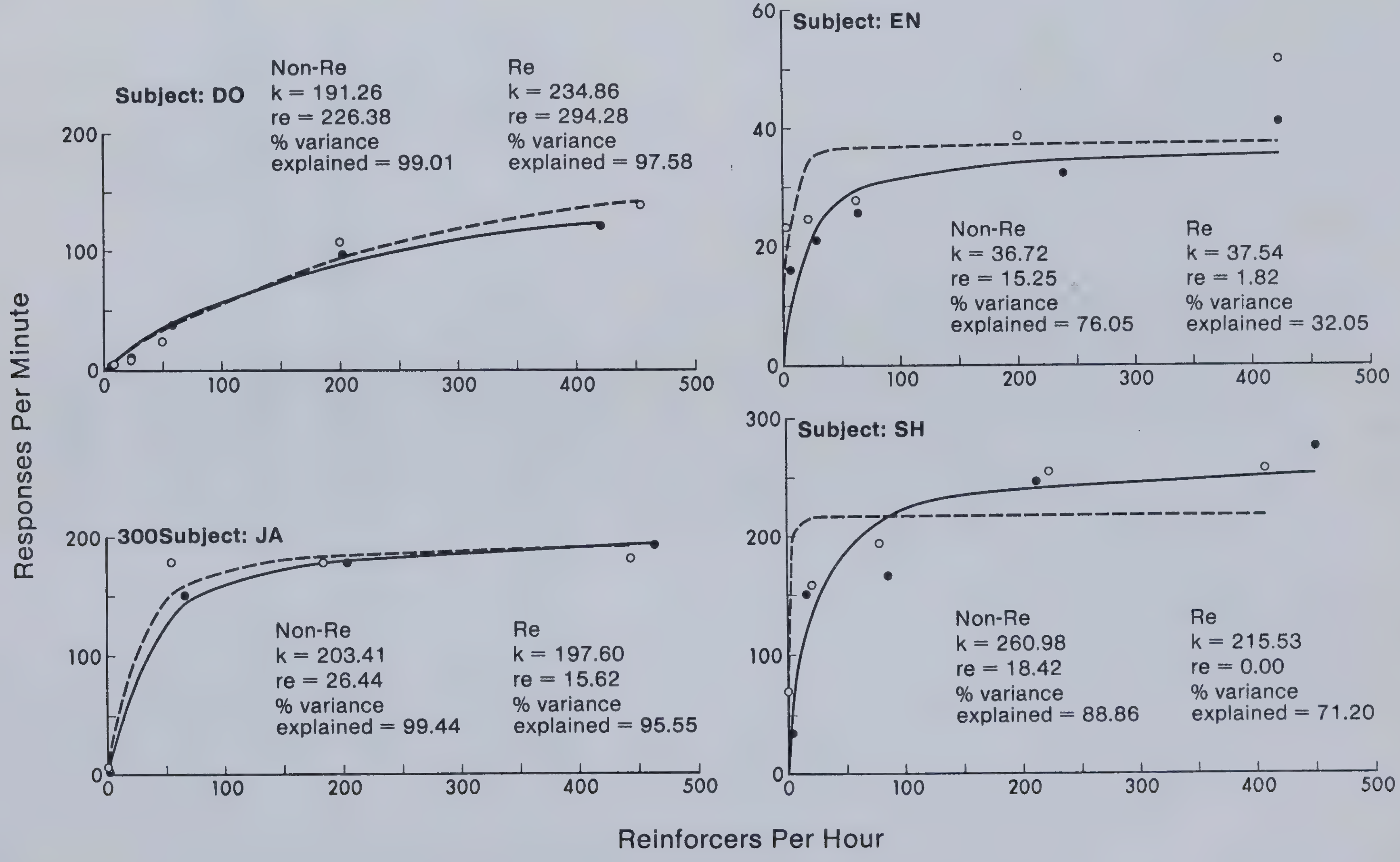

Subject: DO
Non-Re
k = 191.26
re = 226.38
% variance
explained = 99.01
Re
k = 234.86
re = 294.28
% variance
explained = 97.58
Subject: EN
Non-Re
k = 36.72
re = 15.25
% variance
explained = 76.05
Re
k = 37.54
re = 1.82
% variance
explained = 32.05
300Subject: JA
Non-Re
k = 203.41
re = 26.44
% variance
explained = 99.44
Re
k = 197.60
re = 15.62
% variance
explained = 95.55
Subject: SH
Non-Re
k = 260.98
re = 18.42
% variance
explained = 88.86
Re
k = 215.53
re = 0.00
% variance
explained = 71.20
Responses Per Minute
Reinforcers Per Hour

Figure 5

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APPENDIX

Debriefing interview and questionnaire items.

Thank you for taking part in this research. It would be helpful to hear some of your thoughts about the study, and I would like to ask you a few questions. Some of your answers will be tape-recorded, and some will be in the form of written responses to questionnaire items which I will hand to you as we go along. All of your answers are confidential. If you want clarification of any of the questions, please feel free to ask.

GENERAL

1) First of all, could you please give me your general, overall impressions of the study?
2) Can you remember the instructions you were given at the beginning? Can you repeat them, please?
3) As a participant, how did you see your role - what did you think you were supposed to do?
4) Did you form any ideas about what the study might be about? Did these ideas change at any point?
5) How did the ideas you had about what the study might be about affect what you did?
6) What did you think the researcher was particularly interested in?

DISCRIMINATION

a) of SDs

1) What was the function of the red lights at the top of the panel?

2) Could you distinguish among the lights? On what basis?

b) of own responding

1) What determined the speed at which you pressed the button during the experiment?

2) How would you describe the speed at which you pressed? Did this description apply at all times? Why do you think you changed?

DEMAND CHARACTERISTICS

a) task/situational

1) Did you feel obliged or constrained to behave in any particular way during the study? (With regard to pressing the button) What led to this?

b) Experimenter effects

1) Did the researcher's behavior give you any indication (apart from the written instructions) of

   a) What she might be studying?

   b) How well you were performing?

   c) What you should be doing?

REINFORCER VALUE OF POINTS

1) How important to you was the payment of the study?

ADDITIONAL QUESTIONS

1) When lights 4 and 5 were on, you typically got very few, if any, points. Why did you keep on pressing?
2) Did you feel you could stop pressing the button at any time or did you feel you had to keep going? Why did you feel this way?
3) Did you feel you had to try to keep at a steady speed when pressing? Why did you feel this way?
4) How did you get points from the small box? Do you think there was any connection between your button. Pressing and getting free points?
5) Do you think you pressed differently when you were getting free points? In what way?

QUESTIONNAIRE

1) Please rank the lights in order from most to least points:

2) Please estimate how many points you typically got when each light was on:

   light: 1 2 3 4 5

3)

1	2	3	4	5
very slow	slow	moderate	fast	very fast

   On the above scale, estimate you speed of pressing when each light was on.

   light: 1 2 3 4 5

4)

1	2	3	4	5
very stable	stable	in the middle	variable	very variable

   On the above scale, how stable/variable was your speed of pressing

   A) At the beginning of the study

   B) In the middle of the study

   C) At the end of the study

5)

1	2	3	4	5
not at all	slightly	moderately	a fair amount	very much

   On the above scale, to what extent do you think that your speed of pressing was influenced by each of the following:

   a) the amount you were currently earning during one part of a session.

   b) the amount you had earned during the previous part

   c) the amount you anticipated earning during the next part

   d) the amount you had earned the previous day

   e) the total amount you could earn for the entire study

   f) any other factors - please indicate and rate on the scale

6)

1	2	3	4	5
not at all	slightly	moderately	a fair amount	very much

On the above scale, to what extent did you:

a) feel obliged to press the button

b) view the study as a job, as work to be done to earn money

c) feel free to <u>not</u> press the button when a light was on

d) try to "please" the researcher

e) try to perform in accordance with what you thought the researcher was studying

f) try to <u>not</u> perform in accordance with what you thought the researcher was studying

7) Please rate the researcher on the following scales (put a tick at the appropriate point on the scale)

	1	2	3	4	5	
warm	_	_	_	_	_	cold
pleasant	_	_	_	_	_	unpleasant
competent	_	_	_	_	_	incompetent
demanding	_	_	_	_	_	not demanding

8)

1	2	3	4	5
not at all	slightly	moderately	a fair amount	very much

On the above scale, to what extent did the researcher's behavior give you any clues as to:

a) what aspect of your performance she was studying

b) how she expected you to perform

9)

1	2	3	4	5
not at all	slightly	moderately	a fair amount	very much

On the above scale, how important was it to you to earn as many points as possible:

a) at the beginning of the study

b) in the middle of the study